Ontario

Ontario Geological Survey
Open File Report 6137

Lithofacies and Geochemistry of the Lucas Formation in the Subsurface of Southwestern Ontario: A High-Purity Limestone and Potential High-Purity Dolostone Resource

2004

104-0502

Ontario

ONTARIO GEOLOGICAL SURVEY

Open File Report 6137

Lithofacies and Geochemistry of the Lucas Formation in the Subsurface of Southwestern Ontario: A High-Purity Limestone and Potential High-Purity Dolostone Resource

by

M.C. Birchard, M.A. Rutka and F.R. Brunton

2004

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

Birchard, M.C., Rutka, M.A. and Brunton, F.R. 2004. Lithofacies and geochemistry of the Lucas Formation in the subsurface of southwestern Ontario: a high-purity limestone and potential high-purity dolostone resource; Ontario Geological Survey, Open File Report 6137, 180p.

© Queen's Printer for Ontario, 2004

© Queen's Printer for Ontario, 2004.

Open File Reports of the Ontario Geological Survey are available for viewing at the Mines Library in Sudbury, at the Mines and Minerals Information Centre in Toronto, and at the regional Mines and Minerals office whose district includes the area covered by the report (see below).

Copies can be purchased at Publication Sales and the office whose district includes the area covered by the report. Although a particular report may not be in stock at locations other than the Publication Sales office in Sudbury, they can generally be obtained within 3 working days. All telephone, fax, mail and e-mail orders should be directed to the Publication Sales office in Sudbury. Use of VISA or MasterCard ensures the fastest possible service. Cheques or money orders should be made payable to the *Minister of Finance*.

Mines and Minerals Information Centre (MMIC) Tel: (416) 314-3800
Macdonald Block, Room M2-17
900 Bay St.
Toronto, Ontario M7A 1C3

Mines Library Tel: (705) 670-5615
933 Ramsey Lake Road, Level A3
Sudbury, Ontario P3E 6B5

Publication Sales Tel: (705) 670-5691(local)
933 Ramsey Lake Rd., Level A3 1-888-415-9845(toll-free)
Sudbury, Ontario P3E 6B5 Fax: (705) 670-5770
E-mail: pubsales@ndm.gov.on.ca

Regional Mines and Minerals Offices:

Kenora - Suite 104, 810 Robertson St., Kenora P9N 4J2

Kirkland Lake - 10 Government Rd. E., Kirkland Lake P2N 1A8

Red Lake - Box 324, Ontario Government Building, Red Lake P0V 2M0

Sault Ste. Marie - 70 Foster Dr., Ste. 200, Sault Ste. Marie P6A 6V8

Southern Ontario - P.O. Bag Service 43, 126 Old Troy Rd., Tweed K0K 3J0

Sudbury - Level B3, 933 Ramsey Lake Rd., Sudbury P3E 6B5

Thunder Bay - Suite B002, 435 James St. S., Thunder Bay P7E 6S7

Timmins - Ontario Government Complex, P.O. Bag 3060, Hwy. 101 East, South Porcupine P0N 1H0

Toronto - MMIC, Macdonald Block, Room M2-17, 900 Bay St., Toronto M7A 1C3

This report has not received a technical edit. Discrepancies may occur for which the Ontario Ministry of Northern Development and Mines does not assume any liability. Source references are included in the report and users are urged to verify critical information. Recommendations and statements of opinions expressed are those of the author or authors and are not to be construed as statements of government policy.

If you wish to reproduce any of the text, tables or illustrations in this report, please write for permission to the Team Leader, Publication Services, Ministry of Northern Development and Mines, 933 Ramsey Lake Road, Level B4, Sudbury, Ontario P3E 6B5.

Cette publication est disponible en anglais seulement.

Parts of this report may be quoted if credit is given. It is recommended that reference be made in the following form:

Birchard, M.C., Rutka, M.A. and Brunton, F.R. 2004. Lithofacies and geochemistry of the Lucas Formation in the subsurface of southwestern Ontario: a high-purity limestone and potential high-purity dolostone resource; Ontario Geological Survey, Open File Report 6137, 180p.

Contents

Abstract xi

Introduction 1

Study Objectives and Approach 1
  Definitions of Key Terms 3
  Limestone and Dolostone Classification 5

General Geology of Study Area 5
  Regional Setting 5
  Stratigraphy 7
    Distribution, Thickness and Stratigraphic Relationships of the Lucas Formation 10
  Depositional Facies and Distribution of the Lucas Formation 11
    Dolostone and Limestone Distribution 17
    Geochemistry of the Lucas Formation 21
      Rationale 21
      Existing Data 21
      Methodology 22
        Drill Core and Sample Selection 22
        Geochemical Data Analysis 24
      Results 24

Discussion of Results 32
  Accuracy of Dolomitization Estimation 33
  Geochemistry of the Lucas Formation 33
    Regional Geochemical Trends 33
    Interbasinal Geochemical Trends 35
    Lucas Formation Facies 35
      Appalachian Basin Lithofacies 35
        A1 Facies 35
        A3 Facies 36
        A4 Facies 36
        A5 Facies 36
      Michigan Basin Lithofacies 37
        M3 Facies 37
        M4 Facies 37
  Lithofacies Purity and Regional and Vertical Trends in the Lucas Formation 39
      Regional Facies and Limestone and Dolostone Purity 39
        Vertical Trends in Lucas Formation Geochemistry 40
        Regional Trends in Lucas Formation Geochemistry 40
      Controls on Carbonate Purity in the Lucas Formation 44
        Lucas Formation in the Michigan Basin 45

Resource Potential of Lucas Formation Carbonates 47

Summary and Conclusions 48
Limestone and Dolostone Distribution 49
Geochemistry of the Lucas Formation 49
Vertical and Regional Geochemical Trends 49
Resource Potential 50

Acknowledgments 50

References 50

Appendix A. List of Drill Holes by Site Number 55

Appendix B. List of Drill Cuttings and/or Core Samples Logged for this Study 57

Appendix C. Summary of Depositional Lithofacies 61

Appendix D. Drill Core Lithologs 64

Appendix E. Litholog Descriptions Listed by County 123

Appendix F. Existing Geochemical Data for Canada Cement Lafarge Core 85-17 (Drill Hole 28) 159

Appendix G. Sample Locations 161

Appendix H. Analytical Techniques 164

Appendix I. Whole Rock Chemical Analysis of Lucas Formation Samples 166

Appendix J. Trace Element Analysis of Lucas Formation Samples 169

Appendix K. Histograms 171

Metric Conversion Table 180

FIGURES

1. Subcrop area of the Detroit River Group (Lucas Formation forms uppermost unit) and locations of logged and sampled drill cores for this study throughout southwestern Ontario 2
2. Paleozoic bedrock geology of southern Ontario. 4
3. Major structural elements and locations of intracratonic basins of Ontario. 6
4. Devonian stratigraphy of southwestern Ontario and adjacent areas 8
5. Schematic representation of depositional settings showing lateral relationships of Lucas Formation lithofacies in both intracratonic basins. 12
6. Paleogeographic map of southwestern Ontario showing depositional environments during the Eifelian (Middle Devonian). 12
7. Location map for cross-sections A–A', B–B' and C–C' 13
8. Stratigraphic cross-section of Lucas Formation along transect A–A' (Kent to Lambton counties) 14
9. Stratigraphic cross-section of Lucas Formation along transect C–C' (eastern Elgin to western Lambton counties) 15
10. Stratigraphic cross-section of Lucas Formation along transect B–B' (Elgin to Essex counties) 16
11. Location map for cross-sections D–D' and E–E' 18

12. Stratigraphic cross-section D–D' showing limestone and dolostone distribution within the Lucas Formation (Lambton to Kent counties). 19

13. Structural cross-section E–E' showing limestone and dolostone distribution within the Lucas Formation (Essex through to Elgin counties). 20

14. A) Geochemical vertical profiles of Lucas Formation (Cansalt DDH 87-3); and B) Lucas and Dundee formations (Lucas No. 3 – existing data), Essex County........ 25

15. A) Geochemical vertical profiles of Lucas and Dundee formations (Lucas No. 2 – existing data); and B) Amherstburg and Lucas formations (Imperial et al. 813), Essex County........ 26

16. A) Geochemical vertical profiles of Lucas Formation (Consolidated West CT-1, Lake Erie); and B) Lucas and Dundee formations (Consumers 33409, Kent County). 27

17. A) Geochemical vertical profiles of Lucas Formation (OGS-82-2 Chatham) in Kent County; and B) Lucas Formation (Imperial 831) in Lambton County........ 28

18. A) Geochemical vertical profiles of Lucas Formation (Imperial 661 Corunna 18) in Lambton County; and B) Amherstburg and Lucas formations (Consumers Amoco 13076) in Elgin County. 29

19. A) Geochemical vertical profiles of Amherstburg and Lucas formations (OGS-82-3) in Elgin County; and B) Lucas Formation (Canada Cement Lafarge 85-17 – existing data) in Elgin County. 30

20. Geochemical vertical profile of Amherstburg and Lucas formations (OGS-82-1) in Lambton County. 31

21. Scatter plot showing relationship between estimated degree of dolomitization of sampled intervals as determined from core examination, and actual degree of dolomitization based upon MgO content. 32

22. Scatter plot showing A) distribution of % MgO within lithofacies with respect to Appalachian Basin (A1 to A5) and Michigan Basin (M3, M3/4 and M4) lithofacies; and B) % total impurities within lithofacies with respect to Appalachian Basin (A1 to A5) and Michigan Basin (M3, M3/4 and M4) lithofacies. 38

23. Southern cross-section showing regional variability in the geochemistry of the Lucas Formation from Essex through to Elgin counties: A) total impurities, B) CaO, C) MgO and D) MgO+CaO. 41

24. Northern cross-section showing regional variability in the geochemistry of the Lucas Formation from Lambton to Elgin counties: A) total impurities, B) CaO, C) MgO and D) MgO+CaO........ 42

25. Regional variability in the geochemistry of lithofacies A3, Kent to Elgin counties: A) total impurities, B) CaO, C) MgO and D) MgO+CaO........ 43

26. Regional distribution of the 5 diagenetic and/or depositional zones of the Lucas Formation, based upon their carbonate resource potential throughout southwestern Ontario. 46

TABLES

1. Limestone and dolostone classification based on visual estimations of the degree of dolomitization. 5

2. Limestone and dolostone classification suitable for laboratory results. 5

3. List of sample names and the number of samples obtained for each drill hole. 23

4. Limestone and dolostone classification distribution of all Lucas Formation samples (n = 66) based on MgO content........ 33

5. Percentage of high-purity limestone and dolostone samples that meet various specification limits........ 34

6. Distribution of lithofacies samples according to limestone and dolostone classification based on MgO content 36

Abstract

The Middle Devonian (Eifelian-age) Lucas Formation of the Detroit River Group of southwestern Ontario is a current source of high-purity limestone in the Woodstock and Amherstburg areas. A geochemical and lithofacies analysis was conducted to delineate possible controls concerning the spatial distributions of high-purity limestone lithofacies in the subsurface throughout southwestern Ontario. Thirty-seven drill cores and 4 suites of drill cuttings were examined to reconstruct regional paleoenvironments, and 66 samples were collected from the cores at regular intervals for geochemical analysis of 10 major and 6 trace elements.

Nine depositional lithofacies were identified and subdivided into 2 distinct basinal systems: the Michigan Basin and the Appalachian Basin (also referred to as the Allegheny Basin). The Michigan Basin includes the upper sabkha mud flat (M1); lower sabkha mud flat (M2); supratidal to shallow intertidal (M3); and subtidal (M4) lithofacies. The Appalachian (or Allegheny) Basin includes the supratidal to intertidal (A1); marginal marine (A2); subtidal (A3); biostromal (A4); and restricted lagoonal (A5) lithofacies. A maximum of 7 shallowing-upward cycles (brining-upward cycles: subtidal to intertidal lithofacies overlain by evaporites) have been recognized in the Michigan Basin succession. Lithofacies associations indicate that deposition occurred in a shallow marine, low energy, hypersaline environment characterized by extensive sabkha-like tidal flats.

Geochemical analysis of cores indicates considerable spatial and temporal variability of MgO and CaO content throughout the formation. Interbasinal comparison of lithofacies failed to detect marked differences in the geochemical character of individual lithofacies of the Lucas Formation. Dolomite content in Appalachian Basin samples was generally low, with a median of 10% (2.21% MgO), while Michigan Basin samples had a median dolomite content of 89% (19.48% MgO). The amount of total impurities was generally less than 3% for both sedimentary basins. Appalachian Basin supratidal to intertidal (A1) lithofacies have the highest limestone purity (median MgO content of 1.55%, or 7% dolomite), followed by subtidal (A3) lithofacies (MgO median of 2.21%, or 10% dolomite). This finding is potentially significant because much of the high-purity limestone extracted in Oxford County is from the subtidal (A3) lithofacies.

The following regional trends in geochemical and lithological character of the Lucas Formation were observed across the Algonquin Arch: an eastward increase in limestone purity (with respect to both MgO and total impurities content) and lithologic uniformity with depth; and a westerly basinward increase in dolostone purity. In general, high-purity dolostones are likely to be found in the subsurface bordering the south shore of Lake Huron, whereas high-purity limestones are present at or near the surface and in the subsurface in Elgin and parts of Kent, Middlesex and Oxford counties.

Lithofacies and Geochemistry of the Lucas Formation in the Subsurface of Southwestern Ontario – A High-Purity Limestone and Potential High-Purity Dolostone Resource

M.C. Birchard[1], M.A. Rutka[2] and F.R. Brunton[3]

Ontario Geological Survey
Open File Report 6137
2004

---

[1]Present address: Canex Energy Inc., 660, 639 5th Ave. S.W., Calgary, Alberta T2P OM9

[2]Present address: Publication Services Section, Ontario Geological Survey,
933 Ramsey Lake Road, Sudbury, Ontario P3E 6B5

[3]Sedimentary Geoscience Section, Ontario Geological Survey,
933 Ramsey Lake Road, Sudbury, Ontario P3E 6B5

Introduction

Limestone and dolostone, used either directly as crushed stone or calcined to produce lime, are among the most widely used raw materials in the chemical, metallurgical and construction industries. Principal markets include the steel industry, pulp and paper industry, the mining industry, water and sewage treatment, glass and chemical production, soil stabilization, construction products and agriculture.

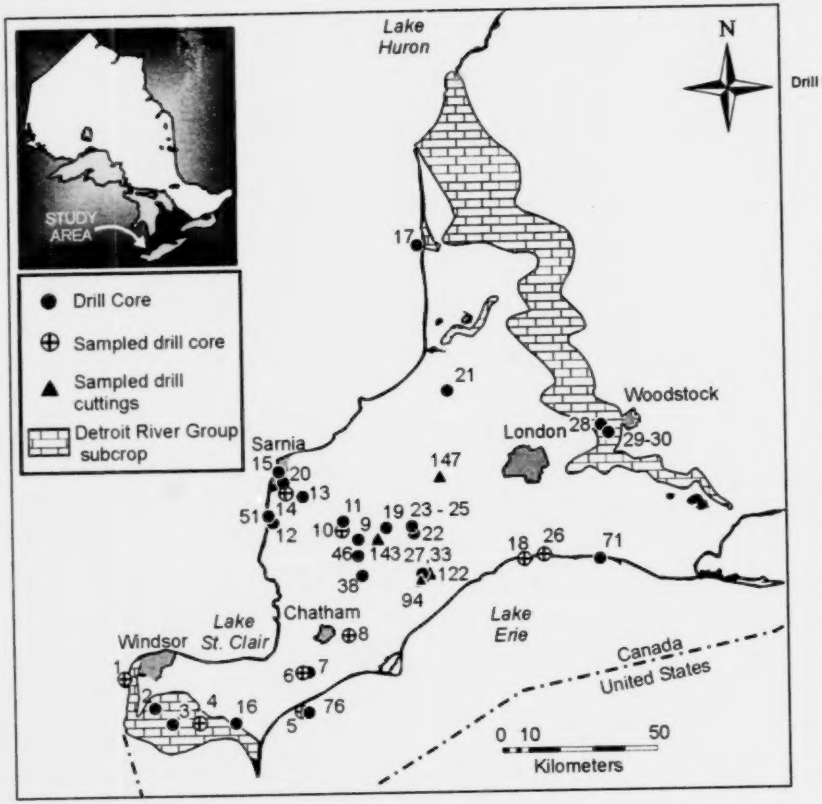
Ontario is fortunate to possess abundant resources of limestone, dolostone and other related carbonates, such as marble and carbonatite. Southwestern Ontario, where much of Ontario's population and the limestone and dolostone market reside, has thick and extensive deposits of carbonate rock suitable for a variety of industrial applications. Despite ample resources, the availability of high-purity limestone and dolostone, which meets the strict physical and chemical specifications required for varied industrial applications, is more limited. Extraction of these high-purity deposits depends upon economic considerations (e.g., extent and thickness of the deposit and the amount of overburden) and accessibility. In recent years, increasing socio-environmental pressures and urban expansion have severely limited access to potential high-purity carbonate deposits. In light of these restrictions, new near-surface resources need to be identified. Alternative extraction practices also need to be considered, such as the establishment of underground mines, which could supply a variety of industrial mineral materials from a number of stratigraphic levels within the Paleozoic sedimentary succession to various markets.

In response to the demand for local sources of high-purity and/or dense carbonate rock, the Ontario Ministry of Northern Development and Mines initiated a regional study of the various stratigraphic units in southwestern Ontario to delineate potential new limestone and dolostone resources. This study examines the Middle Devonian (Eifelian-age) Lucas Formation, which is a historically significant petroleum-producing succession in the subsurface, and is the key source of high-purity limestone in the Woodstock–Ingersoll and Amherstburg areas of southwestern Ontario. As near-surface high-purity limestone resources at these localities become more restricted in their lateral extent, other potentially economic localities need to be identified.

Study Objectives and Approach

This project comprises a lithofacies and geochemical analysis of the Lucas Formation in order to evaluate its potential as a high-purity carbonate rock resource in the subsurface of southwestern Ontario. The main objective of the study was to correlate depositional lithofacies and high-purity carbonate zones throughout the study area. A geochemical analysis was conducted to provide both a quantitative basis for the regional correlations and augment the existing database of the Lucas Formation. Such a geochemical database would also provide information that may lead to future prospects within this economically significant limestone–dolostone succession. Results of this study also contribute to our understanding of the paleogeography of the Michigan and Appalachian basins during Middle Devonian (Eifelian) time.

Thirty-seven drill cores and 4 suites of drill cuttings were selected for lithological and geochemical examination. These cores, most of which are stored at the Petroleum Resources Core Laboratory of the Ontario Ministry of Natural Resources in London, Ontario, were chosen from approximately 80 cores listed by the Petroleum Resources Laboratory (Carter and Trevail 1989) as penetrating part or all of the Lucas Formation. All of the cores examined in this study have good penetration into the Lucas Formation, while most of the remaining cores only penetrate the upper few metres of the formation. Core control is variable over the study area, reflecting the interest of the petroleum industry. As a result, some


Lake Huron
N
STUDY AREA
● Drill Core
⊕ Sampled drill core
▲ Sampled drill cuttings
▨ Detroit River Group subcrop
Sarnia
Woodstock
London
Chatham
Windsor
Lake St. Clair
Lake Erie
Canada
United States
0 10 50
Kilometers
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23 - 25
26
27,33
28
29-30
38
46
51
71
76
94
122
143
147

LIST OF DRILL HOLES BY SITE (MAP) NUMBER

Drill Hole Number	Drill Hole Name	Township, County
1	Cansalt DDH 87-3, Fighting Is.	Sandwich W. Tp., Essex Co.
2	Lucas No. 3	Anderdon Tp., Essex Co.
3	Lucas No. 2	Colchester S. Tp., Essex Co.
4	Imperial et al. 813, Reimer #1	Gosfield S. Tp., Essex Co.
5	Consolidated West CT-1	Lake Erie
6	Consumers 33409	Tilbury E. Tp., Kent Co.
7	Consumers 33408A	Tilbury E. Tp., Kent Co.
8	OGS-82-2	Harwich Tp., Kent Co.
9	Leesa-Imperial 4-27-XIII	Dawn Tp., Lambton Co.
10	Imperial 831	Enniskillen Tp., Lambton Co
11	Imperial 838	Enniskillen Tp., Lambton Co
12	Argor 65-1	Moore Tp., Lambton Co.
13	Imperial 547	Moore Tp., Lambton Co.
14	Imperial 661 Corunna 18	Moore Tp., Lambton Co.
15	M.O.E. Deep Obs. #1	Sarnia Tp., Lambton Co
16	Lucas No. 1	Mersea Tp., Essex Co.
17	Domtar Test #3	Goderich Tp., Huron Co.
18	Consumers Amoco 13076	Lake Erie
19	Leesa-Imperial 1-13-I	Brooke Tp., Lambton Co.
20	Imperial 700 Ref. 11	Sarnia Tp., Lambton Co.
21	Imperial 809	McGillivray Tp, Middlesex Co
22	Mitchell #3	Mosa Tp., Middlesex Co.
23	Walker 502	Mosa Tp., Middlesex Co
24	Allegany Prod. W. 112	Mosa Tp., Middlesex Co
25	Secord 601	Mosa Tp., Middlesex Co.
26	OGS-82-3	Yarmouth Tp., Elgin Co.
27	Cdnoxy Rodney 5-30	Aldborough Tp., Elgin Co.
28	Canada Cement Lafarge 85-17	West Zorra Tp., Oxford Co.
29	Domtar Beachville 72-5	North Oxford Tp., Oxford Co.
30	Domtar Beachville 72-10	North Oxford Tp., Oxford Co
33	Cdnoxy Rodney 6-18	Aldborough Tp., Elgin Co.
38	Brett	Camdon Gore Tp., Kent Co.
46	Leesa-Dawn 19-XIII	Dawn Tp., Lambton Co.
51	OGS-82-1	Moore Tp., Lambton Co
71	Consumers Pan Am 13057	Lake Erie
76	Consolidated West CT-6	Lake Erie
94	Aldborough Oil and Gas #14	Aldborough Tp., Elgin Co
122	Aldborough Oil and Gas #10	Aldborough Tp., Elgin Co.
143	NYK Oil - Monroe No. 1	Euphemia Tp., Lambton Co.
147	Earl-Bolton No. 1	Metcalfe Tp., Middlesex Co.

Figure 1. Subcrop area of the Detroit River Group (Lucas Formation forms uppermost unit) and locations of logged and sampled drill cores for this study throughout southwestern Ontario.

areas, such as parts of Middlesex, Oxford and Elgin counties, where there may be the greatest potential for high-purity limestone, have poor core control, demonstrating the strong need for additional drilling in these areas.

To facilitate referencing of drill holes, all drill cores logged for this study have been assigned numbers ranging from 1 to 76 (Figure 1); the 4 suites of drill cuttings were assigned higher numbers. These numbers, linked to their corresponding well names, as shown in Figure 1 and in Appendix A, are referred to in the text as "drill hole [number]".

Lithologic descriptions of carbonates were made using Dunham's (1962) rock classification as modified by Embry and Klovan (1971). An approximation of the ratio of $MgCO_3$ to $CaCO_3$ (i.e., degree of dolomitization) was also made for each unit. This ratio is based upon the following criteria:

1. visual examination of lithology
2. degree of reaction with dilute HCl (10%)
3. microscopic examination of core after etching with dilute HCl
4. degree of staining with an Alizarin Red S solution

Detailed core examination enabled definition of lithofacies that are representative of a variety of depositional environments, and also allowed preliminary observations to be made regarding

1. lateral and vertical relationships of depositional lithofacies
2. lateral and vertical relationships of diagenetic facies
3. possible correlation of depositional lithofacies to diagenetic lithofacies
4. basinal controls on high-purity limestone and dolostone distribution

A total of 66 samples, collected from 10 drill cores, representing the various carbonate lithofacies of the Lucas Formation, were analyzed for major and trace elements.

DEFINITIONS OF KEY TERMS

High-purity dolostone: Dolostone that contains less than 3% total impurities and at least 97% combined calcium and magnesium carbonates. For the purposes of this report, dolostone has 19.5% to 21.6% MgO content and less than 3% impurities (*after* Hewitt and Vos 1972).

High-purity limestone: Limestone that contains less than 3% total impurities and less than 2% $MgCO_3$, or less than 1% MgO content (*after* Hewitt and Vos 1972).

Impurities: As used in this report, impurities refer to the presence of silica, iron and alumina. If present in significant amounts these, as well as other substances, such as organic matter and heavy metals, may restrict the use of the material in certain industrial applications.

Lime: Lime is the product of heating limestone and dolostone until CO_2 is driven out of the rock, a process referred to as calcination. The 2 main types of lime, high calcium lime and dolomitic lime, are produced by calcination of high calcium limestone and dolostone, respectively.

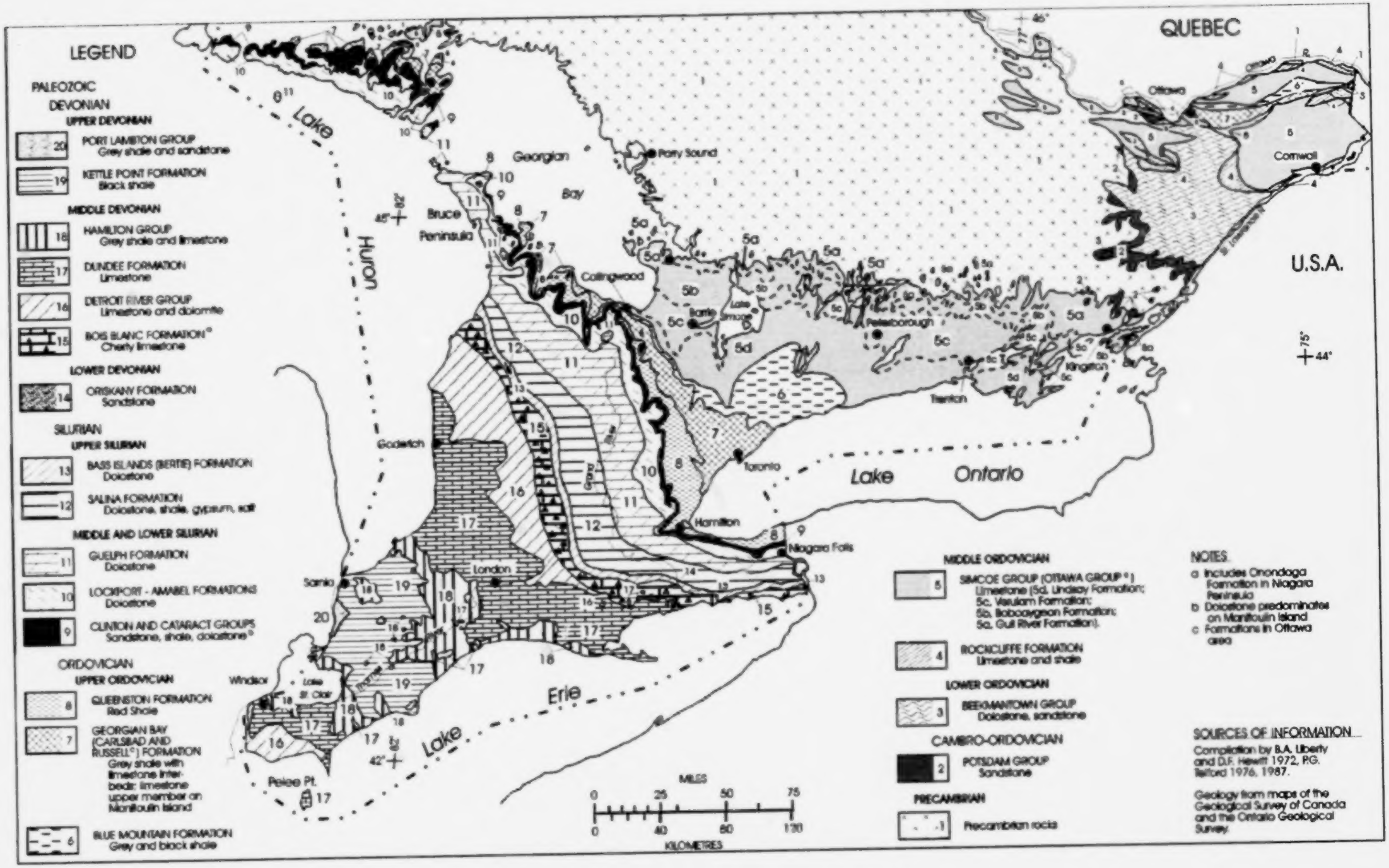

LEGEND
PALEOZOIC
DEVONIAN
UPPER DEVONIAN
20 PORT LAMBTON GROUP Grey shale and sandstone
19 KETTLE POINT FORMATION Black shale
MIDDLE DEVONIAN
18 HAMILTON GROUP Grey shale and limestone
17 DUNDEE FORMATION Limestone
16 DETROIT RIVER GROUP Limestone and dolomite
15 BOIS BLANC FORMATION a Cherty limestone
LOWER DEVONIAN
14 ORISKANY FORMATION Sandstone
SILURIAN
UPPER SILURIAN
13 BASS ISLANDS (BERTIE) FORMATION Dolostone
12 SALINA FORMATION Dolostone, shale, gypsum, salt
MIDDLE AND LOWER SILURIAN
11 GUELPH FORMATION Dolostone
10 LOCKPORT - AMABEL FORMATIONS Dolostone
9 CLINTON AND CATARACT GROUPS Sandstone, shale, dolostone b
ORDOVICIAN
UPPER ORDOVICIAN
8 QUEENSTON FORMATION Red Shale
7 GEORGIAN BAY (CARLSBAD AND RUSSELL c) FORMATION Grey shale with limestone interbeds; limestone upper member on Manitoulin Island
6 BLUE MOUNTAIN FORMATION Grey and black shale
MIDDLE ORDOVICIAN
5 SIMCOE GROUP (OTTAWA GROUP c) Limestone (5d. Lindsay Formation; 5c. Verulam Formation; 5b. Bobcaygeon Formation; 5a. Gull River Formation).
4 ROCKCLIFFE FORMATION Limestone and shale
LOWER ORDOVICIAN
3 BEEKMANTOWN GROUP Dolostone, sandstone
CAMBRO-ORDOVICIAN
2 POTSDAM GROUP Sandstone
PRECAMBRIAN
1 Precambrian rocks
NOTES
a Includes Onondaga Formation in Niagara Peninsula
b Dolostone predominates on Manitoulin Island
c Formations in Ottawa area
SOURCES OF INFORMATION
Compilation by B.A. Liberty and D.F. Hewitt 1972, P.G. Telford 1976, 1987.
Geology from maps of the Geological Survey of Canada and the Ontario Geological Survey.
QUEBEC
U.S.A.
Lake Huron
Georgian Bay
Bruce Peninsula
Lake Ontario
Lake Erie
Lake St. Clair
Ottawa R.
St. Lawrence R.
Ottawa
Cornwall
Kingston
Trenton
Peterborough
Parry Sound
Collingwood
Barrie
Lake Simcoe
Toronto
Hamilton
Niagara Falls
Goderich
Sarnia
London
Windsor
Pelee Pt.
45° 82°
42° 82°
46° 77°
44° 75°
MILES
0
25
50
75
0
40
80
120
KILOMETRES

Figure 2. Paleozoic bedrock geology of southern Ontario.

LIMESTONE AND DOLOSTONE CLASSIFICATION

Limestone and dolostone classification of units described was initially based on the visual estimation of the degree of dolomitization, using Classification #1 (Table 1).

Table 1. Limestone and dolostone classification based on visual estimations of the degree of dolomitization.

Limestone and Dolostone Classification #1	
Classification	**% Dolomite**
Limestone	0–10
Dolomitic limestone	10–40
Calcareous dolomite	40–70
Dolostone	70–100

This classification scheme takes into consideration the difficulties involved in visually estimating the degree of dolomitization when dealing with rocks on the borderline between a limestone and dolostone. Geochemical analysis of some units enabled the more rigid classification scheme of Hewitt and Vos (1972), here referred to as Classification #2 (Table 2).

Table 2. Limestone and dolostone classification suitable for laboratory results. MgO limits hold if the amount of impurities present is relatively small (*from* Hewitt and Vos 1972).

	Limestone and Dolostone Classification #2		
Classification	**%Calcite**	**%Dolomite**	**%MgO**
Limestone	95–100	0–5	0–1.1
Magnesian Limestone	90–95	5–10	1.1–2.1
Dolomitic Limestone	50–90	10–50	2.1–10.8
Calcitic Dolostone	10–50	50–90	10.8–19.5
Dolostone	0–10	90–100	19.5–21.6

General Geology of Study Area

REGIONAL SETTING

Paleozoic sedimentary rocks in southwestern Ontario straddle 2 significant Precambrian basement structures—the Findlay and Algonquin arches—and, therefore, make up parts of the eastern and western sedimentary successions of both the Michigan and Appalachian (also referred to as the Allegheny) basins, respectively (Figures 2 and 3). The Algonquin Arch trends northeast through southwestern Ontario, whereas the Findlay Arch trends northward through southeastern Indiana, western Ohio, and the extreme western regions of southern Ontario. These arches, which are separated by a structural low called the Chatham Sag, were affected by intermittent epeirogenic movements throughout the Paleozoic Era in response to orogenic overthrust loading along the Appalachian Orogen (Bradley 1983; Quinlan and Beaumont 1984). Deposition of Eifelian-age Detroit River Group strata in southern Ontario coincided with Acadian orogenesis within the Appalachians (Johnson 1971; Bradley 1983; Rickard 1984; Quinlan and Beaumont 1984; Ettensohn 1985, 1994). Pysklywec and Mitrovica (1997) have inferred that the depositional history of the late Paleozoic succession in some intracratonic basins of North America (e.g., Williston and Michigan basins) may reflect the interplay of distant subduction zones and temporally associated mantle avalanches beneath cratons and associated regional tilting of cratons (Mitrovica, Beaumont and Jarvis 1989; Coakley, Nadon and Wang 1994). Regional shifts in lithofacies and associated basinal and meteoric fluid migration adjacent to reactivated Precambrian basement structures in overlying Paleozoic strata, in response to multi-million-year duration tectophases and eastward cratonic tilting, may have played an important role in the distribution of high-purity limestone and dolostone lithofacies of the Lucas Formation, which is the uppermost unit of the Detroit River Group.

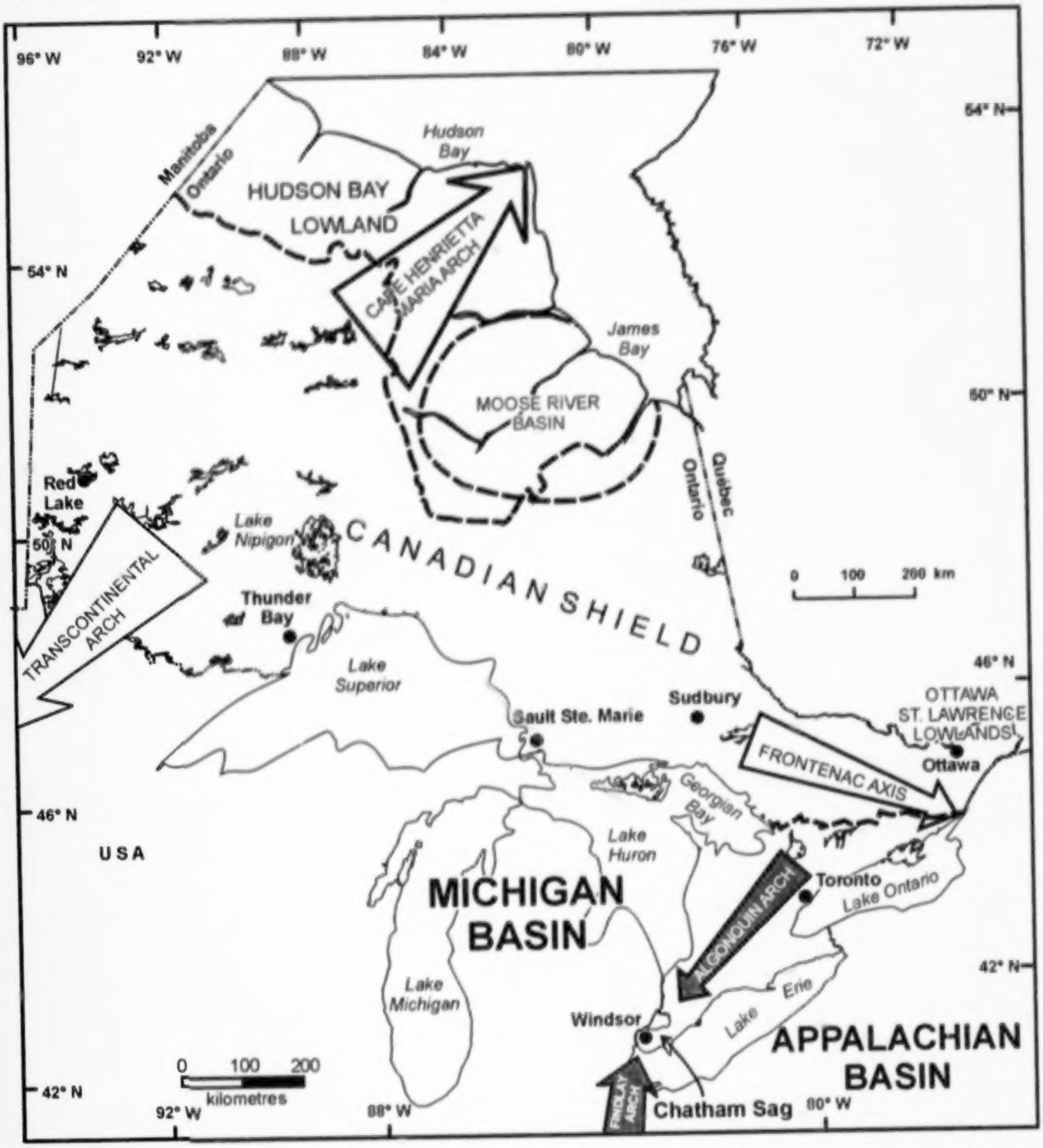

96° W
92° W
88° W
84° W
80° W
76° W
72° W
54° N
50° N
46° N
42° N
Manitoba
Ontario
Hudson Bay
HUDSON BAY
LOWLAND
CAPE HENRIETTA MARIA ARCH
James Bay
MOOSE RIVER BASIN
Quebec
Ontario
Red Lake
Lake Nipigon
CANADIAN SHIELD
TRANSCONTINENTAL ARCH
Thunder Bay
0 100 200 km
Lake Superior
Sault Ste. Marie
Sudbury
OTTAWA
ST. LAWRENCE
LOWLANDS
Ottawa
FRONTENAC AXIS
Georgian Bay
Lake Huron
USA
MICHIGAN
BASIN
ALGONQUIN ARCH
Toronto
Lake Ontario
Lake Michigan
Windsor
Lake Erie
APPALACHIAN
BASIN
0 100 200
kilometres
FINDLAY ARCH
Chatham Sag

Figure 3. Major structural elements and locations of intracratonic basins of Ontario. The study area spans the eastern Michigan Basin, Algonquin Arch and westernmost Appalachian Basin, which are highlighted in the lower right-hand portion of map area.

The Paleozoic rocks of southwestern Ontario are essentially flat lying, having been relatively unaffected by the multiple episodes of intense folding and thrust-faulting that occurred far to the east in the Appalachians. These predominantly marine strata have been subjected to shallow and deeper burial basinal fluid migration associated with episodic regional tilting, subsidence, uplift, marine restriction and karstification spanning late Cambrian through Carboniferous time. North and west of the Algonquin Arch, strata dip gently at 6 to 9 m per kilometre westward into the Michigan Basin. Equivalent-age strata to the south of the arch dip approximately 6 m per kilometre southward into the Appalachian (Allegheny) Basin (Winder and Sanford 1972). Both major and minor faults are evident in the subsurface of southwestern Ontario (Brigham 1971) and some of these faults, such as the Dawn Fault (Lambton County), cut through Detroit River Group strata and show a maximum displacement of 47 m down to the south. Sanford, Thompson and McFall (1985) have proposed that the Paleozoic strata of southwestern Ontario reveal an extensive fracture network, reflecting vertical rotation of fault-bounded blocks, which is a means of relieving stresses set up by orogenic activity occurring at the craton (Laurussia: Ziegler 1988) margins. According to Ziegler (1988, p.15), "Laurussia was formed during the latest Silurian by the welding of Laurentia–Greenland and Fennosarmatia [Baltica] along the Arctic–North Atlantic Caledonian megasuture". These regional-scale structures have resulted in favourable configurations for the migration of basinal fluids, including the stratigraphic and structural entrapment of hydrocarbons and the hydrothermal overprint of dolomitizing fluids (Coniglio et al. 1994; Coniglio, Zheng and Carter 2003). This network of faults and fractures is also reflected in Precambrian basement structures, especially along the eastern margin of the Michigan Basin (Carter and Easton 1990; Carter, Trevail and Easton 1993, 1996; Easton and Carter 1995).

STRATIGRAPHY

In southwestern Ontario, the Lower to Middle Devonian Detroit River Group comprises 3 formations: the basal Sylvania Formation; the middle Amherstburg Formation; and the upper Lucas Formation (Figure 4).

The Sylvania Formation, up to 30 m in thickness, comprises well-sorted, fine- to medium-grade orthoquartzitic sandstones. The formational status of this strandline deposit has been a matter of debate. Some authors have included it as a member of the Amherstburg Formation (Landes 1951; Sanford 1967; Derry Michener Booth and Wahl and OGS 1989a, 1989b), whereas others have treated it as a separate formation within the Detroit River Group (Fagerstrom 1966; Johnson et al. 1992; Russell 1993). Fagerstrom (1971) argued that it should not be included in the Detroit River Group because of its lithologic distinctiveness. The Sylvania Formation sandstone does not crop out in Ontario, but, in the extreme southwest part of the province, occurs within 60 m of surface and pinches out rapidly to the north and east (Winder 1961; Sanford and Brady 1955).

The Amherstburg Formation comprises up to 50 m of grey brown or dark brown, slightly cherty, very bituminous, coral-stromatoporoid rudaceous limestone (Uyeno, Telford and Sanford 1982). Localized reefal development, informally known as the "Formosa Reef Limestone", occurs in the upper part of the formation. These reefs, which are up to 15 m thick and crop out at Formosa, in central-southwest Ontario, occur in the subsurface as a series of lenticular (biostromes) and hummocky (bioherms) skeletal-rich units. The narrow reefal belt trends parallel to the southeastern rim of the Michigan Basin (Sanford 1967). The Amherstburg reefs at Formosa consist of high-purity limestone. Little is known at present about the paleogeographic influences, thicknesses and lithofacies character or occurrences of similar reefal units in the subsurface and their potential as a high-purity limestone resource.

The Lucas Formation is primarily a Michigan Basin unit. In the central part of the basin, the formation consists of dolostone and limestone with interbedded anhydritic dolostone, salt and anhydrite (Sanford 1967; Uyeno, Telford and Sanford 1982). Eastward, toward the basin margin and over the

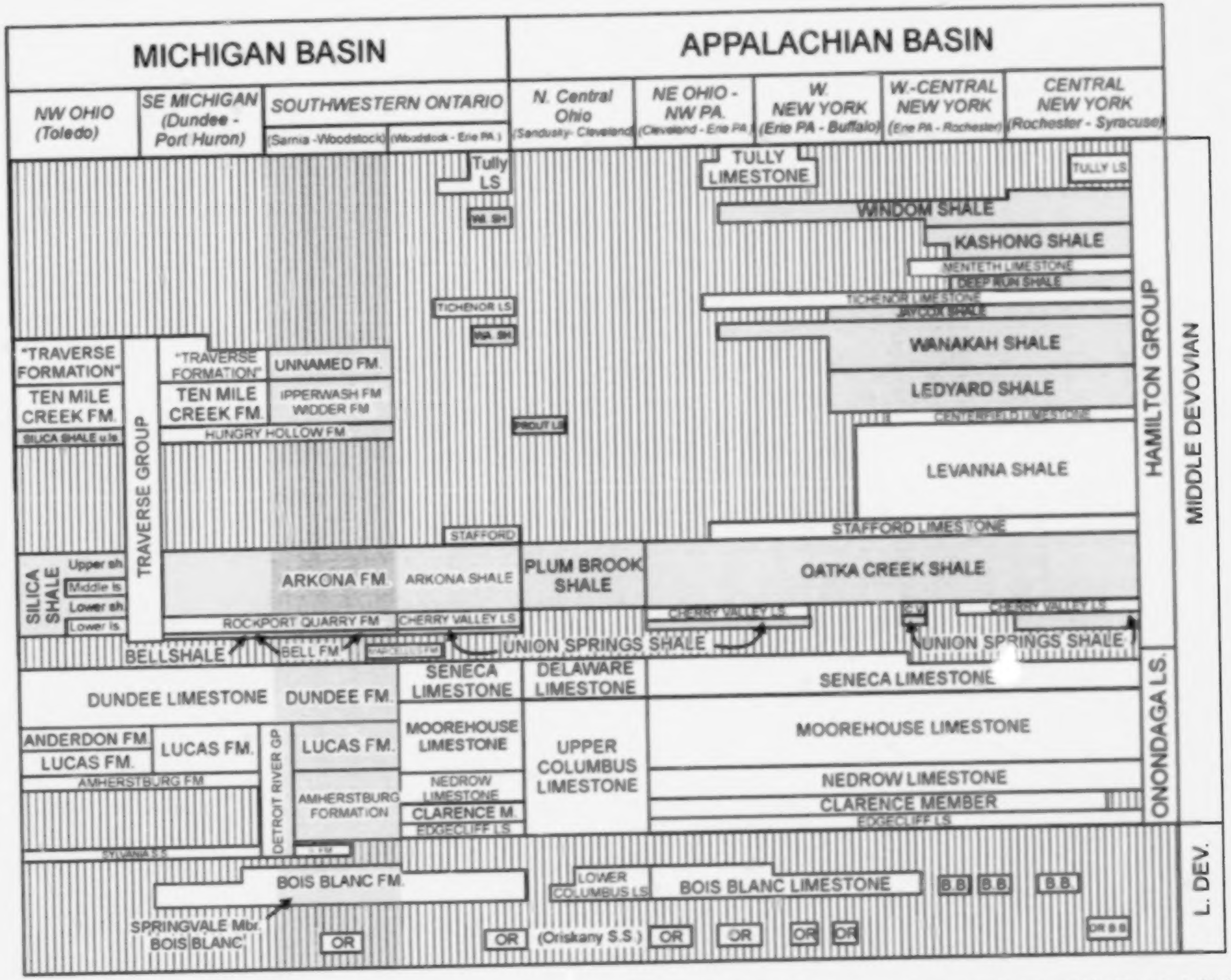

MICHIGAN BASIN
APPALACHIAN BASIN
NW OHIO (Toledo)
SE MICHIGAN (Dundee - Port Huron)
SOUTHWESTERN ONTARIO
(Sarnia -Woodstock)
(Woodstock - Erie PA.)
N. Central Ohio (Sandusky- Cleveland)
NE OHIO - NW PA. (Cleveland - Erie PA.)
W. NEW YORK (Erie PA - Buffalo)
W.-CENTRAL NEW YORK (Erie PA - Rochester)
CENTRAL NEW YORK (Rochester - Syracuse)
MIDDLE DEVOVIAN
L. DEV.
HAMILTON GROUP
ONONDAGA LS.
Tully LS
TULLY LIMESTONE
TULLY LS
WI. SH
WINDOM SHALE
KASHONG SHALE
MENTETH LIMESTONE
DEEP RUN SHALE
TICHENOR LS
TICHENOR LIMESTONE
JAYCOX SHALE
WA. SH
WANAKAH SHALE
LEDYARD SHALE
CENTERFIELD LIMESTONE
LEVANNA SHALE
PROUT LS
"TRAVERSE FORMATION"
TEN MILE CREEK FM.
SILICA SHALE u.ls.
TRAVERSE GROUP
UNNAMED FM.
IPPERWASH FM
WIDDER FM
HUNGRY HOLLOW FM
STAFFORD
STAFFORD LIMESTONE
SILICA SHALE
Upper sh.
Middle ls.
Lower sh.
Lower ls.
ARKONA FM.
ARKONA SHALE
PLUM BROOK SHALE
OATKA CREEK SHALE
ROCKPORT QUARRY FM
CHERRY VALLEY LS.
C.V.
BELLSHALE
BELL FM.
UNION SPRINGS SHALE
DUNDEE LIMESTONE
DUNDEE FM.
SENECA LIMESTONE
DELAWARE LIMESTONE
ANDERDON FM.
LUCAS FM.
DETROIT RIVER GP
MOOREHOUSE LIMESTONE
UPPER COLUMBUS LIMESTONE
AMHERSTBURG FM
AMHERSTBURG FORMATION
NEDROW LIMESTONE
CLARENCE M.
CLARENCE MEMBER
EDGECLIFF LS
SYLVANIA S.S.
BOIS BLANC FM.
LOWER COLUMBUS LS.
BOIS BLANC LIMESTONE
B.B.
SPRINGVALE Mbr. 'BOIS BLANC'
OR
(Oriskany S.S.)
OR B.B.

Figure 4. Devonian stratigraphy of southwestern Ontario and adjacent areas (*modified after* Rickard 1984). The stratigraphic nomenclature used in Ontario is highlighted in grey column under subheading for Sarnia–Woodstock area of southwestern Ontario. The Lucas Formation is the uppermost rock unit of the Detroit River Group in southwestern Ontario. The uppermost Middle Devonian unnamed formation within this column (Rickard 1984) requires further core logging to confirm its distinction from Ipperwash Formation in southwestern Ontario. Abbreviations: BB, Bois Blanc Limestone; Fm, Formation; LS, limestone; Mbr, Member; sh, shale; SS, sandstone.

Algonquin Arch, the formation comprises carbonate platform dolostones and high-purity limestones (Sanford 1967; Uyeno, Telford and Sanford 1982). Throughout most of southwestern Ontario, the Lucas Formation sharply and conformably overlies Amherstburg stromatoporoid-bearing microbial biostromes. Johnson, Russell and Telford (1985) have reported thin anhydrite-gypsum beds, partings and blebs from drill cores of the Lucas Formation. Needle-like moldic porosity and breccia textures, suggestive of evaporite mineral dissolution, are evident in the formation. The variety of depositional and diagenetic lithofacies evident within the Lucas Formation has resulted in the development of a range of definitions and subdivisions for the formation (Lane et al. 1909; Ehlers 1950; Sanford 1967). The Lucas Formation has been subdivided into 3 distinct, mappable units, including 1) undifferentiated Lucas Formation lithofacies; 2) Anderdon Member lithofacies; and 3) sandy limestone lithofacies of the Anderdon Member (Uyeno, Telford and Sanford 1982).

Briefly, these 3 units comprise

1. Lucas Formation (undifferentiated): tan, light brown to grey, laminated, thin- to medium-bedded, fine crystalline, poorly fossiliferous dolostone with dark, bituminous laminations (stylolitized seams). This lithofacies outcrops at the base of the St. Marys Quarry at St. Marys, Ontario, and along the Maitland River near Goderich, Ontario.
2. Anderdon Member: alternating zones of light-tan to brown, medium- to thick-bedded, sparsely fossiliferous, micritic limestone and thick or massive beds of rudaceous, very fossiliferous skeletal limestone. Megafauna include varied low diversity stromatoporoid sponge assemblage involving diagnostic dendroid or digitate amphiporids *Amphipora nattressi* and low domical to laminar forms of *Anostylostroma* and *Syringostroma*; the rugose corals *Eridophyllum* and *Zaphrentis*; tabulate coral *Hexagonaria*; brachiopods *Paraspirifer* and *Brevispirifer*; bryozoans; bivalves; trilobites, gastropods and the rare rostroconch *Conocardium* (Best 1953; Linsley 1968; Fagerstrom 1982; Prosh and Stearn 1993; Klapper and Oliver 1995). This very high-purity limestone unit occurs in the Beachville–Ingersoll area, where it forms almost the entire Lucas Formation. Quarries in this area expose an almost complete section (40 m) of the member (Derry Michener Booth and Wahl and OGS 1989b). The Anderdon Member also occurs beneath central Lake Erie, in the adjacent areas of Elgin, Norfolk and Oxford counties, and in the Amherstburg area of Essex County (Sanford 1967).
3. Sandy limestone facies of the Anderdon Member: buff-coloured, thick- to massive-bedded, medium- to coarse-crystalline, rudaceous limestone and lenses of orthoquartzitic sandstone. This facies forms the top unit of the Anderdon Member in the Lafarge (former Steel Company of Canada) and Carmeuse (Beachville Lime) quarries in the Woodstock–Ingersoll area of southern Ontario. It also occurs in the subsurface in parts of Lambton, Kent, Middlesex and Essex counties (Sanford 1967; Summerson and Swann 1970; Uyeno, Telford and Sanford 1982). Winder and Sanford (1972) interpreted the faceted and frosted quartz grains of this member to be derived from an extremely mature source area. Sanford (1967) interpreted the sands as being of eolian origin.

The undifferentiated Lucas Formation and Anderdon Member lithofacies of the Detroit River Group have been defined solely on the basis of dolostone and limestone lithologies, respectively. Although these units are mappable on a regional scale, a better stratigraphic scheme is necessary in order to carry out further detailed subsurface stratigraphic work and to better delineate potential high-purity limestone and dolostone resources in areas where diagenetic lithofacies show interfingering relationships. Rickard (1984) has demonstrated the usefulness of integrating geophysical logs of boreholes to delineate key stratigraphic units and contact relationships on a regional scale.

In much of southwestern Ontario, the Detroit River Group is disconformably overlain by the Dundee Formation, a 20 to 40 m thick, fossiliferous, argillaceous, cherty, skeletal-bearing, in places rudaceous, limestone. Biota and depositional textures suggest a variety of depositional regimes, ranging from nearshore lagoonal to more open-shelf, deeper subtidal environments (Birchard 1990a, 1990b, 1993). In the southern part of Essex and Kent counties, however, a shallow water equivalent to the Dundee Formation, found to the north and northeast, intervenes between the Detroit River Group and the Dundee Formation. These tan to grey, very fossiliferous, bioclastic dolomitic lime wackestones-packstones-grainstones have been assigned to the "Columbus Formation" (Birchard 1990a, 1990b), although the term is not formally recognized in Ontario. Fossils representative of the "Columbus Formation", as used in this report, commonly include stromatoporoids, solitary and colonial rugose and tabulate corals, large brachiopods, bryozoans and crinoids.

Distribution, Thickness and Stratigraphic Relationships of the Lucas Formation

The distribution and subcrop area of the Detroit River Group (Lucas Formation) is shown in Figure 1. The formation forms the bedrock of a broad belt extending northwestward from west of Simcoe to Lake Huron (Telford and Hamblin 1980). It is also present in Essex County forming small inliers in the Goderich, Grand Bend and Delhi areas (Sanford 1969). Surface exposures are scarce: the most extensive sections occur in quarries located in Amherstburg, Ingersoll and St. Marys (Uyeno, Telford and Sanford 1982; Derry Michener Booth and Wahl and the OGS 1989b). Outcrops occur along the Maitland River, near Goderich, the east shore of Lake Huron and also near Inverhuron, Douglas Point and in the Formosa–Teeswater areas (Sanford 1969; Uyeno, Telford and Sanford 1982).

The Lucas Formation has a fairly uniform thickness of between 20 to 40 m along the Algonquin Arch (eastern margin of the Michigan Basin). In the centre of the Michigan Basin, the formation is more than 365 m thick (Sanford 1967). The formation attains a maximum thickness of approximately 100 m in Ontario in the subsurface of Sarnia Township, Lambton County. The high-purity limestone Anderdon Member forms only a thin veneer at the top of the Lucas Formation in southeastern Michigan and adjacent Essex County, Ontario. It thickens eastward to about 40 m in quarries in the Beachville–Ingersoll area, Oxford County, forming the main rock unit (Uyeno, Telford and Sanford 1982; Derry Michener Booth and Wahl and OGS 1989b).

Despite its varied lithofacies, the Lucas Formation is a distinctive stratigraphic unit. Its lower contact with the Amherstburg Formation is conformable and is marked by a change from dark brown, fine- to coarse-crystalline, bituminous, occasionally cherty, skeletal limestones (Amherstburg Formation) to lighter coloured, micritic limestones and dolostones (Lucas Formation). The upper contact with the overlying Dundee Formation is unconformable. The contact is characterized by a sharp, undulatory (erosive) surface, in places overlain by dolomitic sandy lime wackestones (Birchard 1990a; Birchard and Risk 1990) or by a thin (5 to 10 cm) intraformational conglomerate with tabular dolostone intraclasts set in a micritic limestone matrix (Uyeno, Telford and Sanford 1982). The contact is believed to be diachronous representing the slow transgressive signature of more open-marine Dundee Formation lithofacies onlapping more restricted lithofacies of the Lucas Formation (Sparling 1985; Birchard and Risk 1990).

The Lucas Formation in southwestern Ontario is generally believed to be Eifelian in age (Sanford 1967; Fagerstrom 1971; Winder and Sanford 1972; Sparling 1985; Rickard 1984; Johnson and Klapper 1992; Klapper and Oliver 1995). It is correlated with the Lucas Formation of Michigan, the middle part of the Columbus Limestone of north-central Ohio, and the Moorehouse Member of the Onondaga Limestone of New York (Rickard 1984; Sparling 1985; Oliver 1981). Uyeno, Telford and Sanford (1982) incorrectly placed the lower part of the Lucas Formation within the Emsian (Early Devonian).

DEPOSITIONAL FACIES AND DISTRIBUTION OF THE LUCAS FORMATION

Although the 3 lithological units of Uyeno, Telford and Sanford (1982) can be mapped regionally, complications arise in the application of these terms in areas where there is an interfingering of limestone and dolostone lithologies. Therefore, a facies analysis approach was considered necessary for the detailed nature of this study.

During logging of the 37 Lucas Formation drill cores for this study (*see* Figure 1; Appendixes A and B), a total of 9 lithofacies, representative of a variety of depositional environments, were defined. These lithofacies are listed below as typical of their locations in the Michigan and Appalachian basins. Detailed lithofacies summaries are given in Appendix C and lithologs for each logged well are listed in Appendixes D and E.

Michigan Basin lithofacies:	**M1**: Upper sabkha mud flat facies
	M2: Lower sabkha mud flat facies
	M3: Supratidal to shallow intertidal facies
	M4: Subtidal facies
Appalachian Basin lithofacies:	**A1**: Supratidal to intertidal facies
	A2: Marginal marine facies
	A3: Subtidal facies
	A4: Biostromal facies (proximal: A4P; distal: A4D)
	A5: Restricted lagoonal facies

Lithofacies of the Lucas Formation in this study area have been subdivided into 2 distinct basinal systems, reflecting the fact that the Michigan and Appalachian basins had very different depositional systems (Figures 5 and 6). The Michigan Basin system is generally characterized as a low-energy, shallow-water evaporitic environment, while the Appalachian Basin was a slightly deeper water, higher energy, more open, marine depositional system. The 2 basins were probably largely separated throughout most of the Eifelian interval represented by deposition of the Lucas Formation, with waters having higher salinity in the Michigan Basin than in the Appalachian Basin. The difference in salinity is evidenced by a more diverse and abundant faunal assemblage in the Appalachian Basin, while sediments in the Michigan Basin are, in large part, poorly fossiliferous.

These paleoenvironmental reconstructions are based on analysis of lateral and vertical facies relationships within the Lucas Formation. There is considerable regional variation in the distribution of depositional and diagenetic facies. This is best illustrated by reference to 3 geographic areas: 1) the Michigan Basin (northwest part of the study area); 2) the northwest flank of the Appalachian Basin; and 3) the southeast part of the study area. In general, the Lucas Formation is typically a dolostone with interbedded anhydrite to the north of the Algonquin Arch, in the Michigan Basin. South of the Algonquin Arch, in the Appalachian Basin, the Lucas Formation is a limestone (Sanford 1967). An interfingering of these gross lithologies occurs in Essex County and in Enniskillen Township, Lambton County.

In the Michigan Basin, in the northwest part of the study area (Lambton County, northwest Middlesex County), the Lucas Formation thickens from a minimum of 25 m in the southeastern part of Lambton County to approximately 100 m in Sarnia Township, Lambton County (Figures 7 to 10). In this area, Lucas Formation lithofacies of the Michigan Basin are typically microcrystalline to very fine crystalline dolostones. Anhydrite and anhydritic dolostone interbeds are common in deeper parts of the

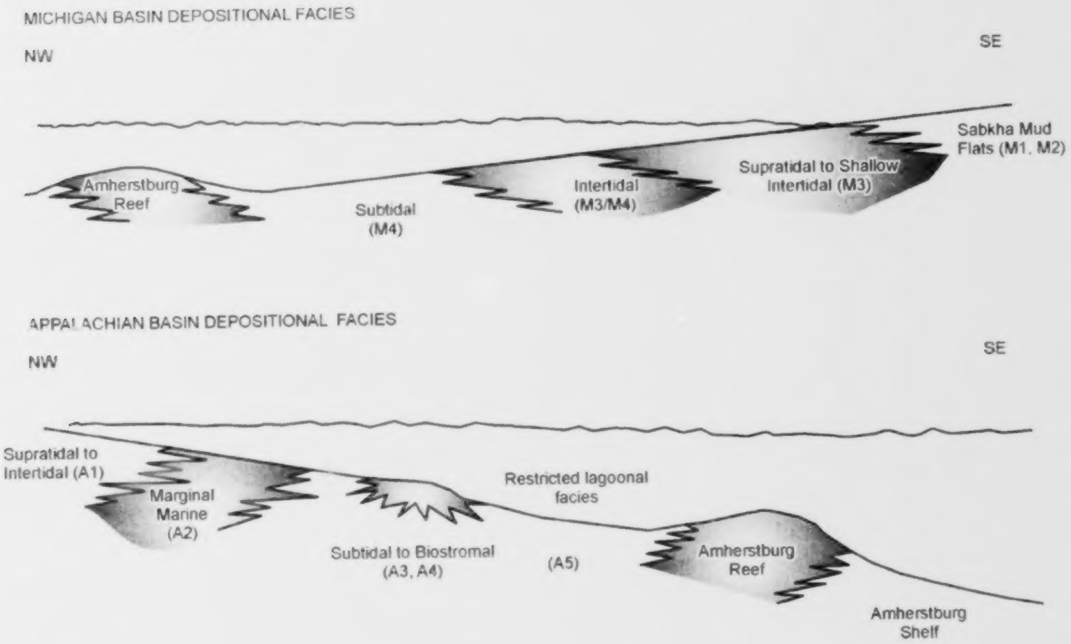

MICHIGAN BASIN DEPOSITIONAL FACIES
NW
SE
Sabkha Mud Flats (M1, M2)
Supratidal to Shallow Intertidal (M3)
Intertidal (M3/M4)
Amherstburg Reef
Subtidal (M4)
APPALACHIAN BASIN DEPOSITIONAL FACIES
NW
SE
Supratidal to Intertidal (A1)
Marginal Marine (A2)
Restricted lagoonal facies
Subtidal to Biostromal (A3, A4)
(A5)
Amherstburg Reef
Amherstburg Shelf

Figure 5. Schematic representation of depositional settings showing lateral relationships of Lucas Formation lithofacies in both intracratonic basins.

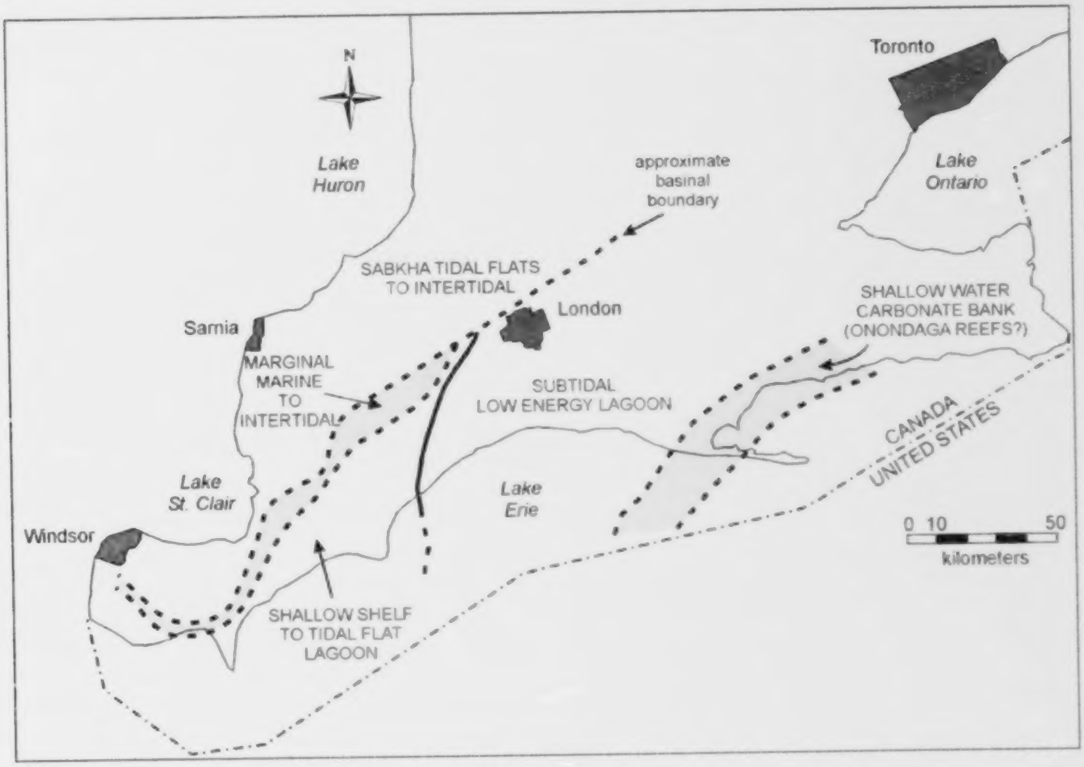

N
Lake Huron
Toronto
Lake Ontario
approximate basinal boundary
SABKHA TIDAL FLATS TO INTERTIDAL
London
Sarnia
MARGINAL MARINE TO INTERTIDAL
SUBTIDAL LOW ENERGY LAGOON
SHALLOW WATER CARBONATE BANK (ONONDAGA REEFS?)
CANADA
UNITED STATES
Lake St. Clair
Lake Erie
Windsor
SHALLOW SHELF TO TIDAL FLAT LAGOON
0 10 50
kilometers

Figure 6. Paleogeographic map of southwestern Ontario showing depositional environments during the Eifelian (Middle Devonian).

basin and up to 7 cycles of dolomite capped by anhydrite may be identified from wells (e.g., drill hole 15) located in Sarnia Township, Lambton County. A repetition of shallow subtidal to supratidal lithofacies (M4 to M3) in the Michigan Basin of southwestern Ontario suggests that only minor fluctuations in sea level occurred throughout the depositional history of the Lucas Formation. Anhydrite and anhydritic dolostone beds pinch out to the southeast toward the margin of the Michigan Basin. The upper few metres of the Lucas Formation in the Michigan Basin is more fossiliferous than underlying beds and may represent a freshening of waters at the end of Detroit River time in the Michigan Basin. This upper unit is generally limestone with dolomitic limestone interbeds in contrast to underlying higher purity dolostone. Orthoquartzitic sands and sandy limestone beds commonly found in the Lucas Formation of the Appalachian Basin are absent in this area of the Michigan Basin, suggesting that transport of terrigenous clastics, presumably originating from the area of the arch, was predominantly directed toward the southeast, into the Appalachian Basin.

On the northwest flank of the Appalachian Basin (Kent, south Lambton, southwestern Middlesex, and western Elgin counties), the Lucas Formation is generally 20 to 30 m thick. Lithofacies here vary considerably in gross lithology and fossil content and reflect more normal marine depositional environs. The abundant and diverse marine invertebrate fauna indicates that normal marine salinities prevailed in this area of the Appalachian Basin throughout the depositional history of the Lucas Formation. Carbonate units here, in contrast to the Michigan Basin, are more rudaceous (increased skeletal components) and more representative of higher energy environments. Coarse packstone and rudstone units and thin biostromal lenses (facies A4: bindstone, floatstone and bafflestone textures) are common.

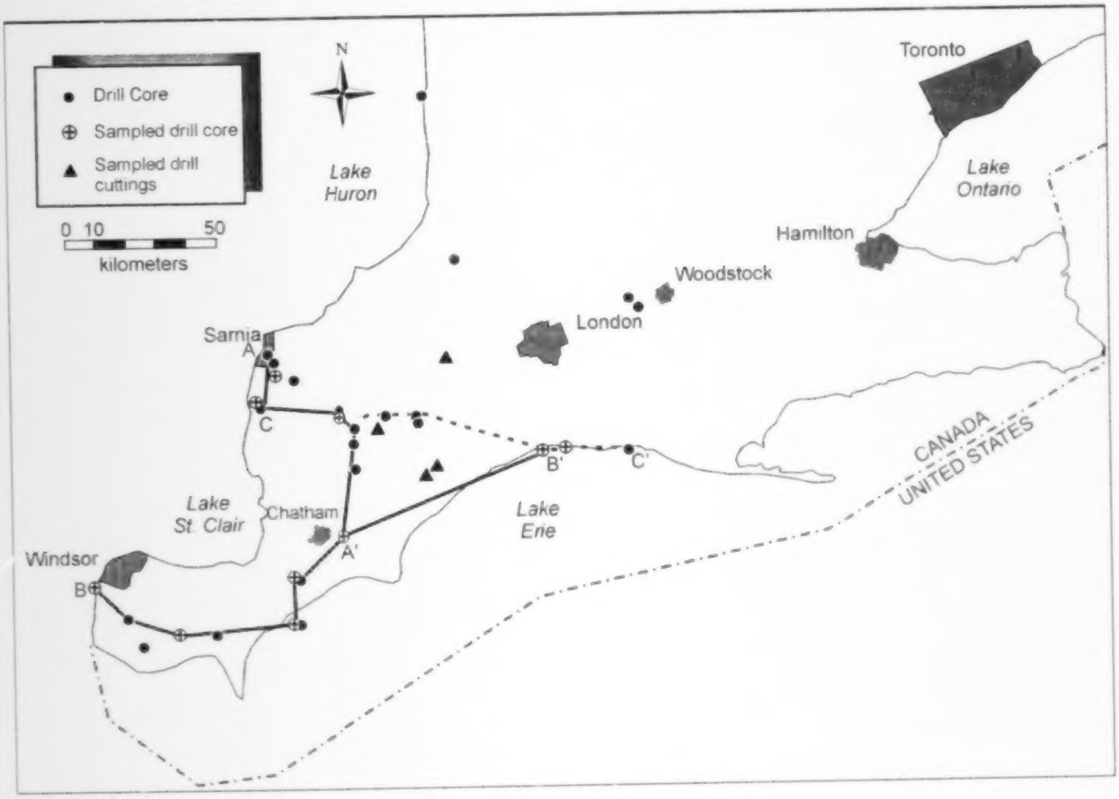


Figure 7. Location map for cross-sections A–A', B–B' and C–C' (Figures 8, 9 and 10, respectively). These cross-sections illustrate the changes in thickness and depositional and diagenetic lithofacies of the Lucas Formation in the Appalachian Basin and Michigan Basin.

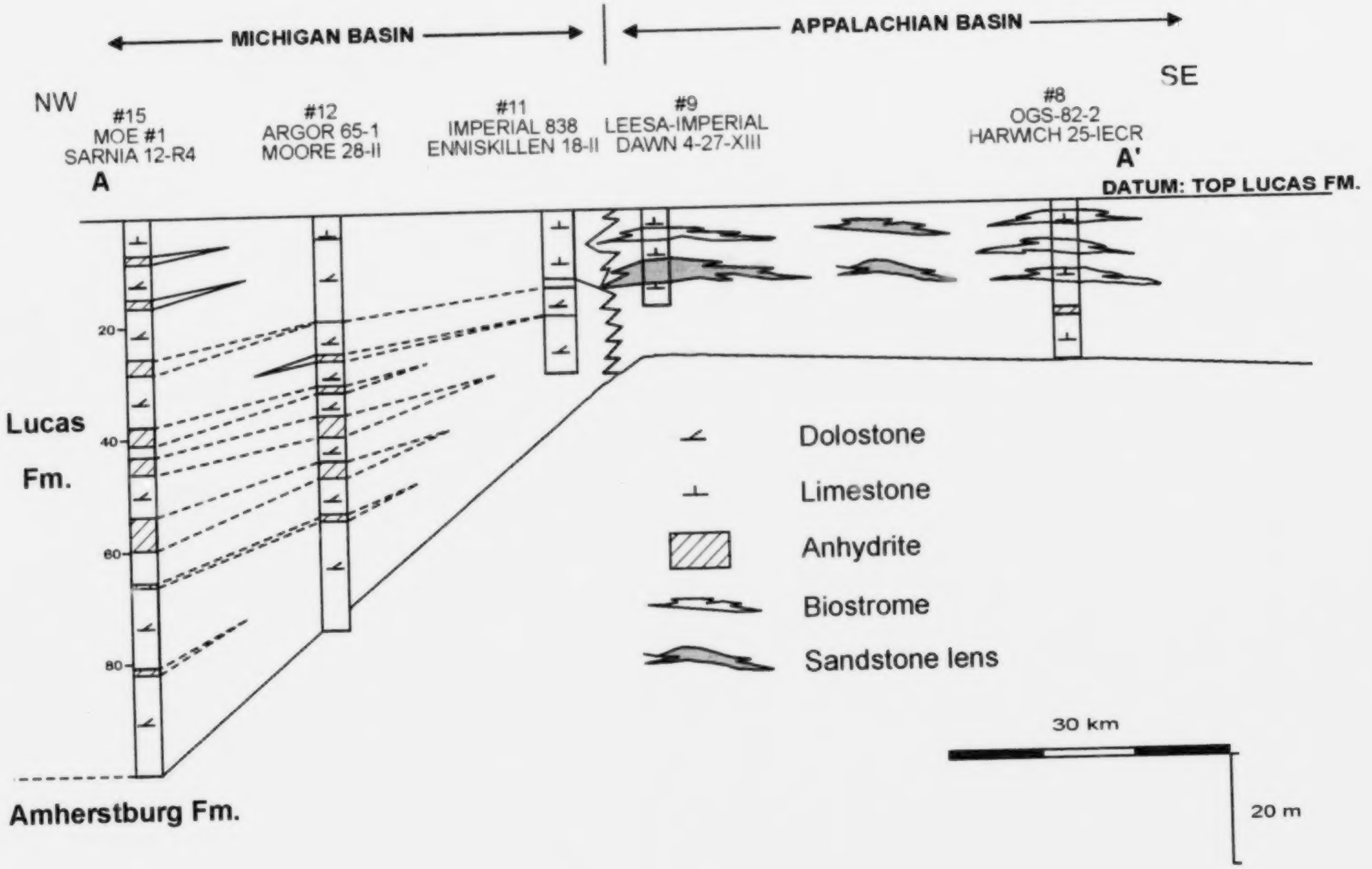

MICHIGAN BASIN
APPALACHIAN BASIN
NW
SE
#15
MOE #1
SARNIA 12-R4
A
#12
ARGOR 65-1
MOORE 28-II
#11
IMPERIAL 838
ENNISKILLEN 18-II
#9
LEESA-IMPERIAL
DAWN 4-27-XIII
#8
OGS-82-2
HARWCH 25-IECR
A'
DATUM: TOP LUCAS FM.
20
40
60
80
Lucas
Fm.
Amherstburg Fm.
Dolostone
Limestone
Anhydrite
Biostrome
Sandstone lens
30 km
20 m

Figure 8. Stratigraphic cross-section of Lucas Formation along transect A–A' (Kent to Lambton counties) (*see* Figure 7 for the location of the cross-section).

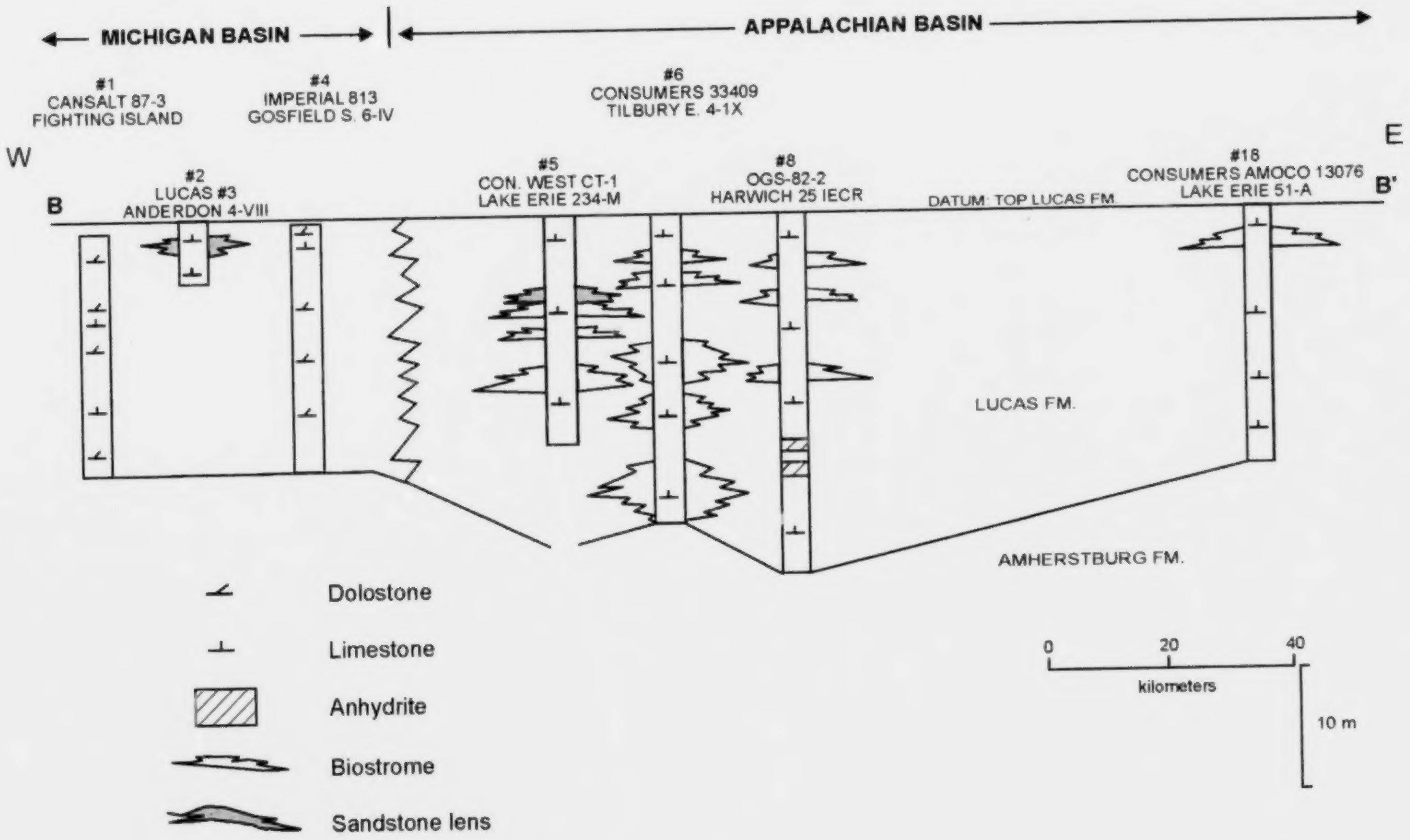

MICHIGAN BASIN
APPALACHIAN BASIN
#1
CANSALT 87-3
FIGHTING ISLAND
#4
IMPERIAL 813
GOSFIELD S. 6-IV
#6
CONSUMERS 33409
TILBURY E. 4-1X
W
E
#2
LUCAS #3
ANDERDON 4-VIII
#5
CON. WEST CT-1
LAKE ERIE 234-M
#8
OGS-82-2
HARWICH 25 IECR
#18
CONSUMERS AMOCO 13076
LAKE ERIE 51-A
B
B'
DATUM: TOP LUCAS FM.
LUCAS FM.
AMHERSTBURG FM.
Dolostone
Limestone
Anhydrite
Biostrome
Sandstone lens
0
20
40
kilometers
10 m

Figure 9. Stratigraphic cross-section of Lucas Formation along transect C–C' (eastern Elgin to western Lambton counties) (*see* Figure 7 for the location of the cross-section).

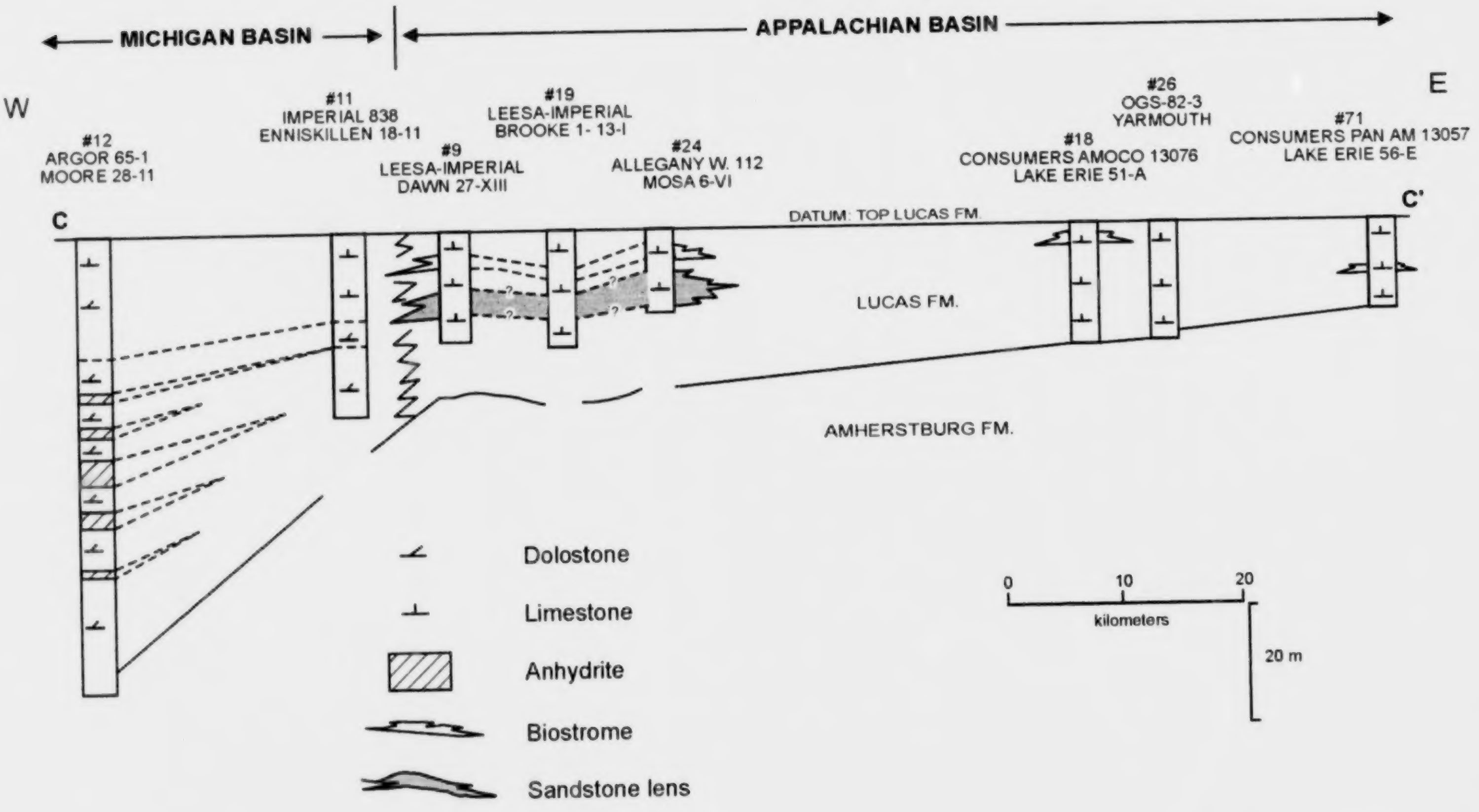

MICHIGAN BASIN
APPALACHIAN BASIN
W
E
#12
ARGOR 65-1
MOORE 28-11
#11
IMPERIAL 838
ENNISKILLEN 18-11
#9
LEESA-IMPERIAL
DAWN 27-XIII
#19
LEESA-IMPERIAL
BROOKE 1- 13-I
#24
ALLEGANY W. 112
MOSA 6-VI
#18
CONSUMERS AMOCO 13076
LAKE ERIE 51-A
#26
OGS-82-3
YARMOUTH
#71
CONSUMERS PAN AM 13057
LAKE ERIE 56-E
C
C'
DATUM: TOP LUCAS FM.
LUCAS FM.
AMHERSTBURG FM.
?
Dolostone
Limestone
Anhydrite
Biostrome
Sandstone lens
0
10
20
kilometers
20 m

Figure 10. Stratigraphic cross-section of Lucas Formation along transect B–B' (Elgin to Essex counties) (*see* Figure 7 for the location of the cross-section).

The marginal marine lithofacies (facies A2) or quartzitic sandy facies of the Anderdon Member (Uyeno, Telford and Sanford 1982) is found only in the Appalachian Basin. It is well developed, as seen in quarries in the Ingersoll area and in southeast Lambton and southwestern Middlesex counties (drill holes 9, 19 and 22 to 25). This lithofacies is characterized by the presence of thick orthoquartzitic sandstone and sandy limestone beds interbedded with coarse, fossiliferous biostromal to rudaceous lenses. The sandstones or sandy limestones are generally massive to planar to cross-stratified. This marginal marine facies is interpreted here as being characteristic of a broad tidal flat environment (partly eolian in origin; Sanford 1967) which existed along the northern flank of the basin during this depositional phase of the Lucas Formation. This tidal flat environment graded northward into shallow intertidal and supratidal lithofacies, interfingering with Michigan Basin facies (*see* Figure 6).

In the southeasternmost part of the study area, a potentially and economically significant high-purity limestone facies occurs: the Anderdon Member of Uyeno, Telford and Sanford (1982). Surface and subsurface exposures of the Lucas Formation in the Woodstock–Ingersoll and Port Stanley areas, respectively, consist almost exclusively of 20 to 30 m thick sections of dense, micritic limestone (*see* Figures 9 and 10; *also see* lithologs for drill holes 18, 26, 28 in Appendix D). This limestone unit, included in the Appalachian subtidal facies (A3), consists primarily of light tan to brown, medium- to thick-bedded, moderately fossiliferous, dense micritic lime mudstones and wackestones. Quartz sandstone and sandy limestone pulses do not appear to be present in this locality. This facies is interpreted as representing deposition within a broad, shallow subtidal lagoonal or platform setting that may have existed behind a reef complex to the southeast (*see* Figure 6). This back-reef or lagoonal interpretation is supported by the occurrence of stromatoporoid-coral biostromes and bioherms that occur at the top of the Lucas Formation in the Port Dover area (Birchard 1990a). The rapid change from coarse-grained, higher energy, shallow subtidal and marginal marine lithofacies in the northwesternmost part of the Appalachian Basin to low energy, micritic subtidal lagoonal facies in the southeasternmost portion of the study area suggests possibly deeper water conditions in the Appalachian Basin.

Dolostone and Limestone Distribution

Previous workers have mapped the gross dolostone–limestone lithofacies boundaries of the Lucas Formation as being roughly coincidental with the transition from the southeast margin of the Michigan Basin to the northern margin of the Appalachian Basin (Best 1953; Sanford 1967). This interpretation is supported in this study (Figures 11, 12 and 13). Cross-sections D–D′ (*see* Figure 12) and E–E′ (*see* Figure 13) are stratigraphic and structural cross-sections, respectively, showing the regional variation in the diagenetic facies of the Lucas Formation from the Michigan Basin into the Appalachian Basin. The proportions of dolomite present for each lithologic unit (as determined from core examination, *see* Appendixes D and E), were grouped into one of the gross range of 1) limestone, 2) dolomitic limestone, 3) calcareous dolostone and 4) dolostone of Classification #1 (*see* Table 1) in order to construct the sections.

Noncarbonate lithologies are not shown on these sections, but were included in the gross carbonate lithology depending upon their bounding carbonate units. For example, in the MOE #1 well (drill hole 15), Sarnia Township (*see* Figure 12), a number of anhydrite beds that are bounded by high-purity dolostone have been included in the gross dolostone lithology. Stratigraphic cross-section D–D′ illustrates both the change in thickness of the Lucas Formation and variations in diagenetic facies from the Michigan to Appalachian basins. Note:

- the rapid thickening of the Lucas Formation into the Michigan Basin,
- a limestone to dolomitic limestone cap at the top of the Lucas Formation in the Michigan Basin,
- the pinch-out of dolostone between the Imperial 831 (drill hole 10, Enniskillen Township) and Leesa Imperial 4-27-XIII (drill hole 9, Dawn Township) wells.

Drill hole OGS-82-1 (drill hole 51) lacks the limestone cap seen in other Michigan Basin drill holes and more than likely reflects misplacement of the upper contact of the Lucas Formation in that core log (*see* Figure 12).

The change in diagenetic facies from predominantly calcareous dolostone and dolostone lithologies to limestone lithologies, from Enniskillen to Dawn township, is roughly coincidental with the location of the west-trending Dawn Fault (*see* Figure 12). This fault, located near the northern boundary of Dawn Township, is about 15 km long and has a maximum displacement of 47 m (Brigham 1971). Depositional lithofacies change drastically away from this fault zone. Orthoquartzitic sand and sandy limestone facies of the Appalachian Basin (facies A2) are found exclusively south of the approximate position of the Dawn Fault. This fault position may also delineate the boundary of lateral movement of diagenetic fluids in the Michigan and Appalachian basins, such that dolomitizing fluids influencing the Detroit River Group have been essentially restricted to the Michigan Basin north of this location. Diagenetic facies patterns of the Lucas Formation in this area indicate that this diagenetic front may extend along-strike of the fault trending toward the axis of the Algonquin Arch. Fossiliferous normal marine facies, characteristic of the Appalachian Basin, are restricted to locations south of the inferred position of the Dawn Fault.

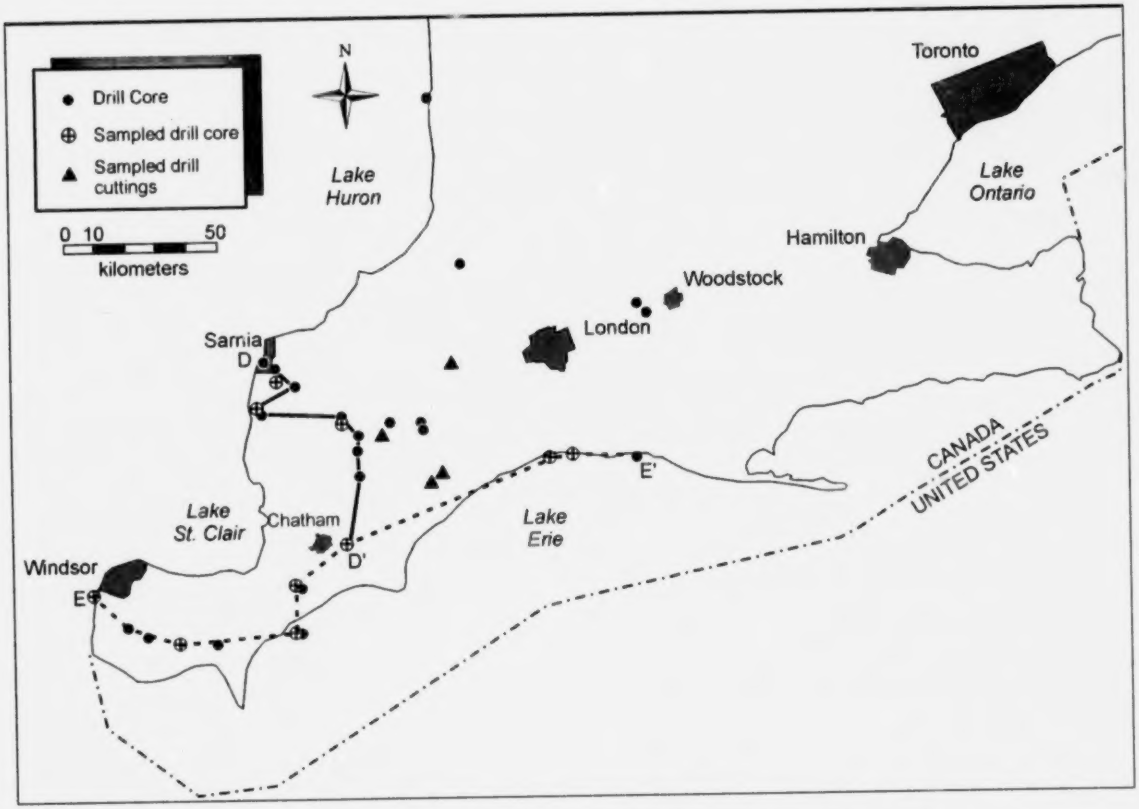

● Drill Core
⊕ Sampled drill core
▲ Sampled drill cuttings
0 10 50
kilometers
N
Lake Huron
Toronto
Lake Ontario
Hamilton
Woodstock
London
Sarnia
D
Lake St. Clair
Chatham
D'
E'
Lake Erie
Windsor
E
CANADA
UNITED STATES

Figure 11. Location map for cross-sections D–D' and E–E' (Figures 12 and 13, respectively).

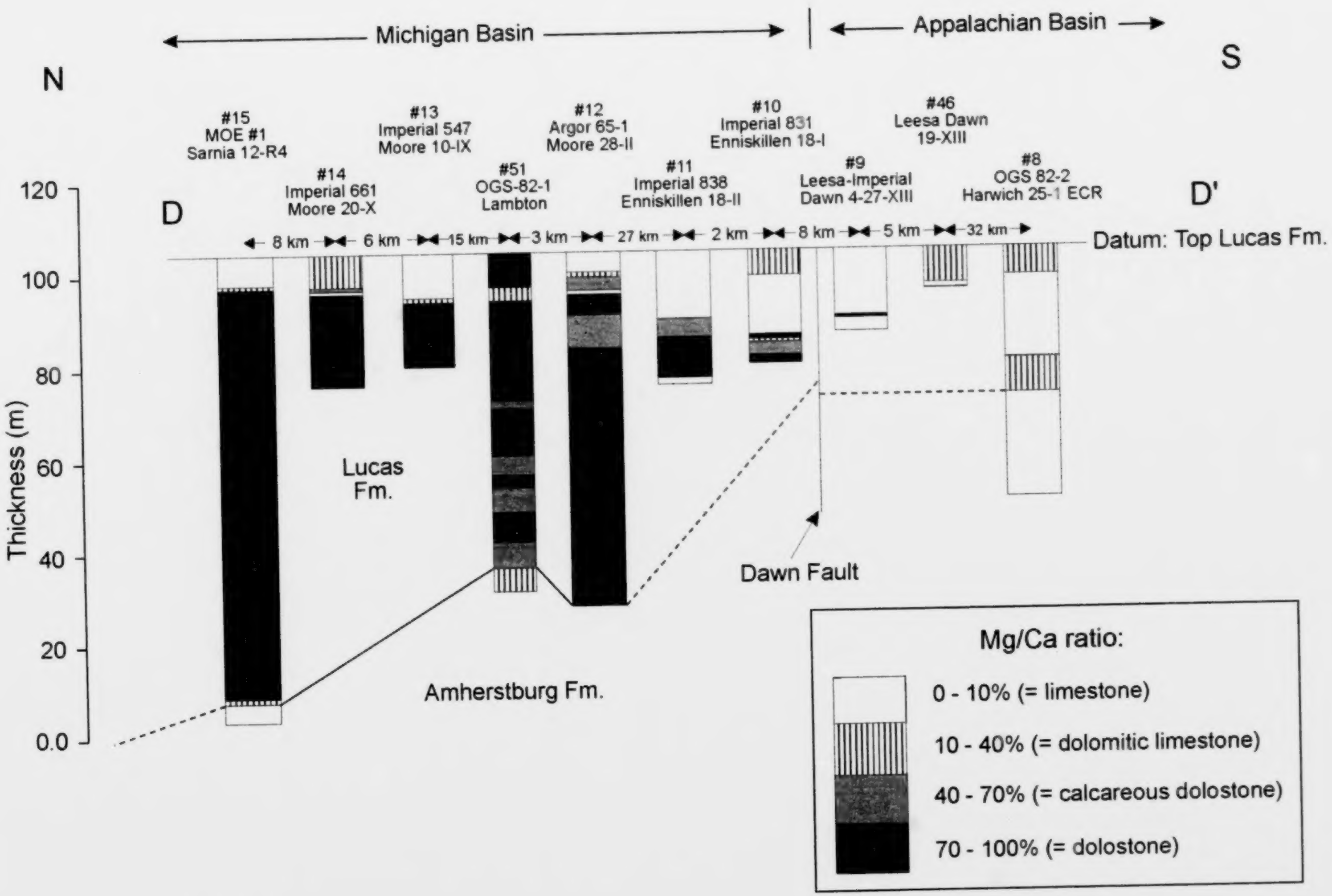

Michigan Basin
Appalachian Basin
N
S
D
D'
#15 MOE #1 Sarnia 12-R4
#14 Imperial 661 Moore 20-X
#13 Imperial 547 Moore 10-IX
#51 OGS-82-1 Lambton
#12 Argor 65-1 Moore 28-II
#11 Imperial 838 Enniskillen 18-II
#10 Imperial 831 Enniskillen 18-I
#9 Leesa-Imperial Dawn 4-27-XIII
#46 Leesa Dawn 19-XIII
#8 OGS 82-2 Harwich 25-1 ECR
8 km
6 km
15 km
3 km
27 km
2 km
8 km
5 km
32 km
Datum: Top Lucas Fm.
Thickness (m)
120
100
80
60
40
20
0.0
Lucas Fm.
Amherstburg Fm.
Dawn Fault
Mg/Ca ratio:
0 - 10% (= limestone)
10 - 40% (= dolomitic limestone)
40 - 70% (= calcareous dolostone)
70 - 100% (= dolostone)

Figure 12. Stratigraphic cross-section D–D' showing limestone and dolostone distribution within the Lucas Formation (Lambton to Kent counties) (*see* Figure 11 for the location of the cross-section).

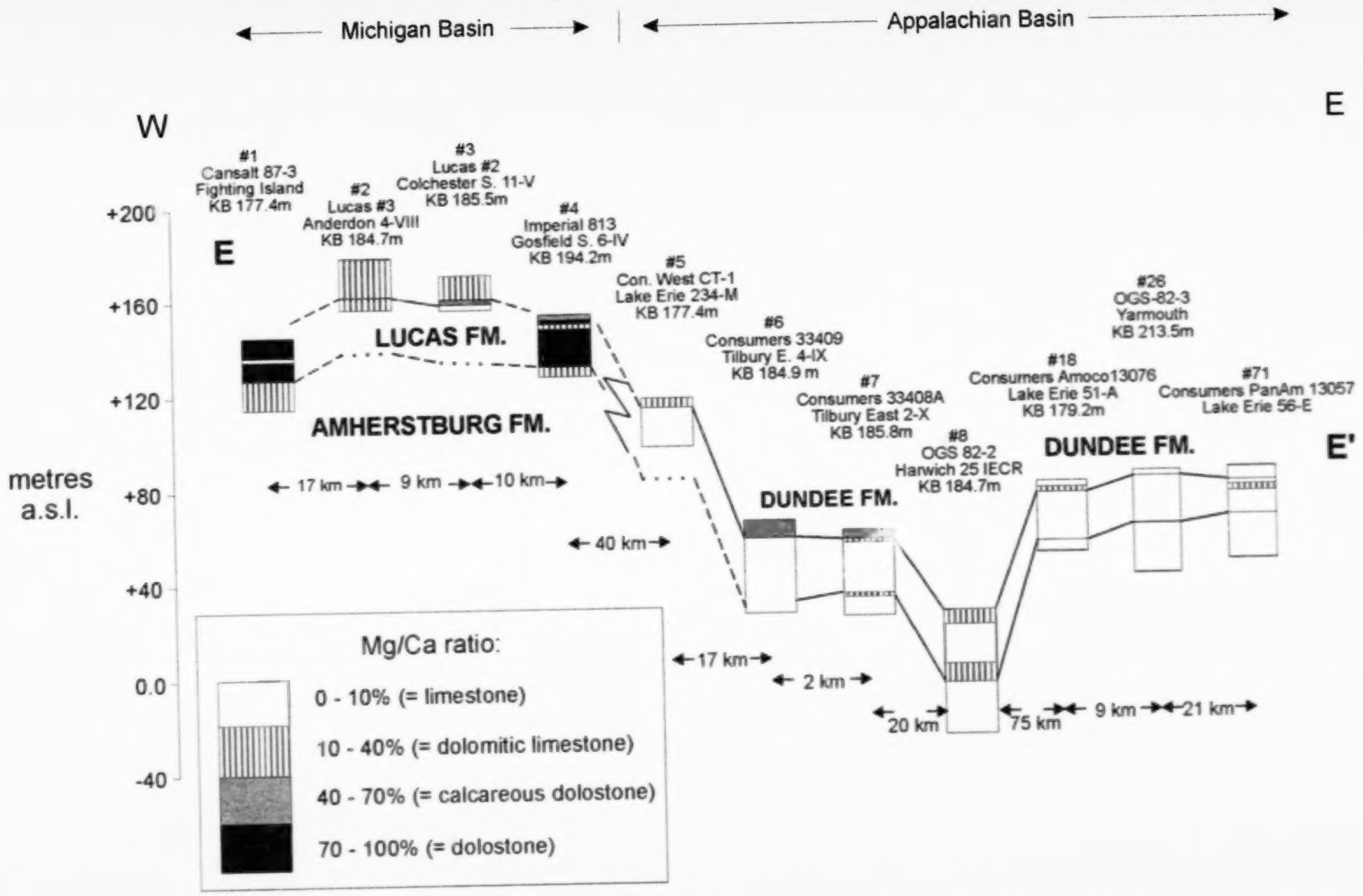

Michigan Basin
Appalachian Basin
W
E
E
E'
metres a.s.l.
+200
+160
+120
+80
+40
0.0
-40
#1
Cansalt 87-3
Fighting Island
KB 177.4m
#2
Lucas #3
Anderdon 4-VIII
KB 184.7m
#3
Lucas #2
Colchester S. 11-V
KB 185.5m
#4
Imperial 813
Gosfield S. 6-IV
KB 194.2m
#5
Con. West CT-1
Lake Erie 234-M
KB 177.4m
#6
Consumers 33409
Tilbury E. 4-IX
KB 184.9 m
#7
Consumers 33408A
Tilbury East 2-X
KB 185.8m
#8
OGS 82-2
Harwich 25 IECR
KB 184.7m
#18
Consumers Amoco13076
Lake Erie 51-A
KB 179.2m
#26
OGS-82-3
Yarmouth
KB 213.5m
#71
Consumers PanAm 13057
Lake Erie 56-E
LUCAS FM.
AMHERSTBURG FM.
DUNDEE FM.
DUNDEE FM.
17 km
9 km
10 km
40 km
17 km
2 km
20 km
75 km
9 km
21 km
Mg/Ca ratio:
0 - 10% (= limestone)
10 - 40% (= dolomitic limestone)
40 - 70% (= calcareous dolostone)
70 - 100% (= dolostone)

Figure 13. Structural cross-section E–E' showing limestone and dolostone distribution within the Lucas Formation (Essex through to Elgin counties) (*see* Figure 11 for the location of the cross-section).

Cross-section E–E′ (*see* Figure 13) is a structural cross-section constructed from wells in Essex County (on the edge of the Findlay Arch) through Kent County (in the vicinity of the Chatham Sag) to Elgin County. The Lucas Formation is approximately 20 to 30 m thick throughout this area and changes from a predominantly high-purity limestone lithofacies in Kent and Elgin counties to a dolomitic facies in Essex County. Depositional lithofacies of the Michigan and Appalachian basins interfinger in the Essex County area. Orthoquartzitic sands and sandy limestone and dolomite beds commonly occur near the top of the Lucas Formation in this vicinity, as well (*see* Figure 9; *see also* lithologs in Appendix D). Sandy carbonate stringers occur proximal to the Findlay Arch in Essex County and are absent in wells immediately to the east in Kent County, away from the arch. This is reflected in the lateral change from marginal marine terrigenous sandy units to fossiliferous subtidal and biostromal facies characteristic of slightly deeper more open marine waters.

Lucas Formation lithofacies characteristic of Appalachian Basin environs occur only in the southernmost part of Essex County, near Amherstburg. The Lucas Formation, in most of the remainder of Essex County, is more comparable to Michigan Basin paleoenvironments, although more detailed work needs to be done to verify this interpretation. The orthoquartzitic sands and sandy limestone intervals observed in Lucas Formation cores from Essex County are also found at the top of the Lucas Formation in the Lafarge (former Stelco Steel) quarry near Ingersoll, Ontario (Uyeno, Telford and Sanford 1982; Derry Michener Booth and Wahl and OGS 1989b). These sandy limestones and sandstone lenses, previously called Columbus Formation (Ehlers and Stumm 1951) and subsequently reclassified as sandy Anderdon Member of the Lucas Formation (Sanford 1967), may have been sourced from the Algonquin Arch or from sources well to the southwest. The absence of thick sandy carbonate units in deeper portions of the Michigan Basin area suggests a short lived and proximal eolian(?) southeasterly source (eolian reworking of the underlying Sylvania Formation sandstone?).

Geochemistry of the Lucas Formation

RATIONALE

A geochemical analysis of the Lucas Formation was conducted primarily to provide a quantitative basis for determining whether a correlation exists between depositional facies and high-purity carbonate zones. Should geochemical characterization of the various facies indicate a correlation, regional and stratigraphic delineation of high-purity limestone and dolostone zones in the subsurface and surface would be greatly simplified. The geochemical information obtained during this study augments the existing database for the Lucas Formation and will make a substantial contribution to the existing geochemical database for Paleozoic carbonate strata in southwestern Ontario.

EXISTING DATA

Geochemical data on the Lucas Formation has been reported from quarries near St. Marys (St. Marys Cement Co. quarry), Ingersoll (Lafarge Canada Inc. Woodstock quarry; Beachville Ltd. quarries; Stelco Steel quarry), and Amherstburg (MacGregor and Amherst quarries) (Derry Michener Booth and Wahl and OGS 1989a, 1989b; Kelly 1996). A few cores penetrating the Lucas Formation have also been sampled for geochemical analyses by the then staff geologist of the Ontario Ministry of Northern Development and Mines (MNDM), Southwestern Ontario District Office in London, Ontario (Kelly 1996), the results of which are included in this report. Cored wells with geochemical data include (*see* Figure 1 for location of wells)

1. CdnOxy Rodney 5-30 (drill hole 27), Elgin County, Aldborough Township
2. Lucas No. 3 (drill hole 2), Essex County, Anderdon Township
3. Lucas No. 2 (drill hole 3), Essex County, Colchester South Township
4. S-82-2 (drill hole 8), Kent County, Harwich Township

Sample data from the wells in Elgin and Essex counties are representative of only the uppermost part of the Lucas Formation, as none of these wells penetrates more than 4 to 5 m into the Lucas Formation. Samples from the Lucas No. 3 and Lucas No. 2 wells are representative of an interfingering of Appalachian Basin shallow water (A1 and A2) facies and Michigan Basin supratidal to intertidal (M3) facies. Samples from OGS-82-2 are representative of the subtidal (A3) facies.

Geochemical data are also included (Appendix F) for a series of samples obtained from a core (Canada Cement Lafarge core 85-17, drill hole 28) drilled adjacent to the Canada Cement Lafarge Quarry near Ingersoll, Ontario. The data listed from the Lucas Formation at this quarry are representative of the Appalachian subtidal facies (A3). This lithofacies comprises dense, micritic lime mudstones that accumulated in a shallow lagoon that extended across much of Elgin and part of Middlesex counties.

Other geochemical data are the result of an Ontario Prospector's Assistance Program (OPAP) Grant proposal (Grant #OP92-337) submitted to the Mineral Development Section of MNDM to sample the high-calcium Lucas Formation, as well as the overlying Dundee and underlying Amherstburg formations from the Port Stanley drill core (OGS-82-3). Channel samples were analyzed for whole rock major element oxides and selected trace elements. This core was also resampled for this study (drill hole 26).

METHODOLOGY

Drill Core and Sample Selection

Ten drill cores, all having good penetration through the Lucas Formation and intersecting at least one formational contact, but preferably both contacts (such as drill holes 6, 8, 18, 26 and 51), were selected for sampling (Table 3; *see* Figure 1). Five of the drill holes (1, 4, 10, 14 and 51) occur within the Michigan Basin and 5 (drill holes 5, 6, 8, 18 and 26) within the Appalachian Basin, thus providing adequate regional coverage of the Lucas Formation throughout the study area.

A total of 71 samples were selected for analysis of whole rock major element oxides and selected trace elements. Sixty-six of these samples were from the Lucas Formation, the remaining 5 samples from the sandy Anderdon Member and the Amherstburg Formation. Sampling of the drill cores was done in such a way as to ensure both adequate representation of each hole and of the various carbonate lithofacies within the Lucas Formation. Samples (approximately 20 g each) were taken at fairly regular intervals down each hole. Interval length, however, varied from hole to hole, ranging anywhere from 1.5 to 8.6 m (but generally averaging 3 m), depending on the length of core available. The number of samples obtained per drill core ranged from 5 to 11. Highly sandy (mostly from facies A2) and argillaceous intervals were generally avoided. Table 3 lists the sample names used for each of the drill cores.

Table 3. List of sample names and the number of samples obtained for each drill hole.

Sample Name	Drill Hole Name	Drill Hole Number (this study)	Number of Samples
CMS	OGS-82-3	26	5
CNS	Cansalt DDH 87-3	1	5
CON3	Consumers 33409	6	4
CONA	Consumers Amoco 13076	18	6
CWT	Consolidated West CT-1	5	7
IMPC	Imperial 661 Corunna 18	14	6
IMPE	Imperial 831	10	6
IMPR	Imperial et al. 813	4	7
LAMB	OGS-82-1	51	10
OGS	OGS-82-2	8	10

All predominantly carbonate lithofacies of the Lucas Formation were sampled, the number of samples obtained from each lithofacies generally reflecting the relative abundance of the lithofacies. The number of samples obtained from each facies is listed below:

Facies		Number of Samples
A1 supratidal to intertidal		4
A3 subtidal		20
A1/A3		2
A4 biostromal (proximal and distal)		4
A5 restricted lagoonal		2
	Subtotal	32
M3 supratidal to shallow intertidal		12
M4 subtidal		12
M3/M4		10
	Subtotal	34
	Total	66

Sample locations are shown on the lithologs in Appendix D and the depths at which they were taken are tabulated in Appendix G.

Samples were analyzed for 10 major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, K, Na and P) and 6 trace elements (Pb, Zn, Cu, Ni, Cr and V) at the Geochemistry Labs, University of Western Ontario, London, Ontario. The analyses were conducted in 2 separate batches. The first batch of 41 samples (those prefixed OGS, CNS, CON3, CONA, IMPC and IMPR) were analyzed during August 1992, and the remaining 30 samples (CWT, IMPE, CMS and LAMB) during February 1993. Both sets of samples were prepared and analyzed similarly to maximize accuracy and to enable utilization and comparison of both sets of data. A brief description of the analytical techniques used is presented in Appendix H.

Trace elements likely to pose environmental problems during stone processing were determined. Analyses for zinc were also undertaken because anomalous amounts of this element, along with the presence of strontium, lead and fluorine, may indicate the presence of Mississippi Valley-type ore mineralization (Johnson and Sorensen 1981).

Geochemical Data Analysis

Statistical summaries and a series of histograms, line plots and scatter plots were utilized as aids in drawing preliminary conclusions regarding regional and vertical trends and possible correlations that may exist between lithofacies and high-purity carbonate intervals within the Lucas Formation. Suspected correlations were verified using regression analysis. Unfortunately, the extent to which the Lucas Formation geochemical data could be analyzed in this manner was restricted by the relatively small size of the data set, especially when the set was further divided into smaller groups. Only the results of the 66 Lucas Formation samples obtained during this study were statistically analyzed; the above-mentioned pre-existing geochemical data were not included due to possible discrepancies that may occur in sample preparation and analytical techniques followed by other laboratories. However, the additional geochemical data did contribute to the overall understanding and interpretations of the regional geochemical character of the formation.

The Lucas Formation data set was examined as a whole and also with respect to lithofacies, individual drill holes and regional location. Results of samples from units assigned to 2 facies, such as CMS-1, which was taken from a unit measured as facies A1/A3, were generally placed in both facies data sets for analysis. Limestone and dolostone classification of analyzed samples allowed the use of the more rigid scheme of Hewitt and Vos (1972).

RESULTS

Results of the major and trace element analyses are presented in Appendixes I and J. Selected histograms and statistical summaries of the major element data with respect to the Lucas Formation as a whole, the various lithofacies and depositional basin are shown in Appendix K; these are referred to throughout the text. Trace element data were not examined as thoroughly, but observed trends and abnormally high values are discussed.

Some of the geochemical data (CaO, MgO, SiO_2, Al_2O_3 and Fe_2O_3) of key interest to the limestone industry are presented graphically against drill core vertical profiles showing gross lithology and lithofacies subdivisions (Figures 14 to 20). Existing geochemical data from drill holes Lucas No. 2 and No. 3 (Kelly 1996), Canada Cement Lafarge (*see* Appendix F), and OGS-82-2 (Kelly 1996) have also been incorporated into these graphs. The gross lithologies portrayed on these profiles are based on both lithological examination and geochemical data. Because of the use of results from the former, gross limestone and dolomitization classifications are based on Classification #1 (*see* Table 1).

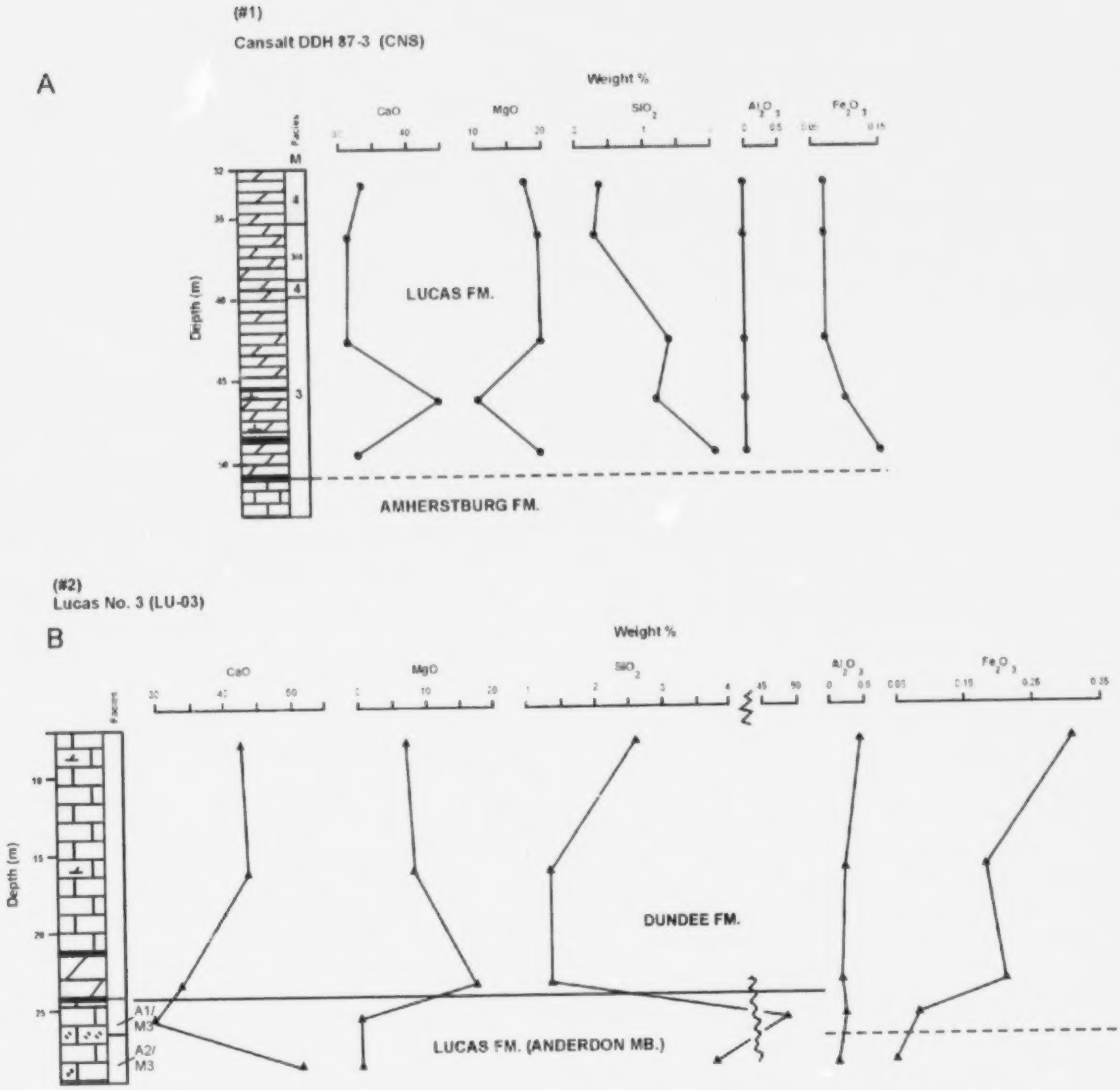
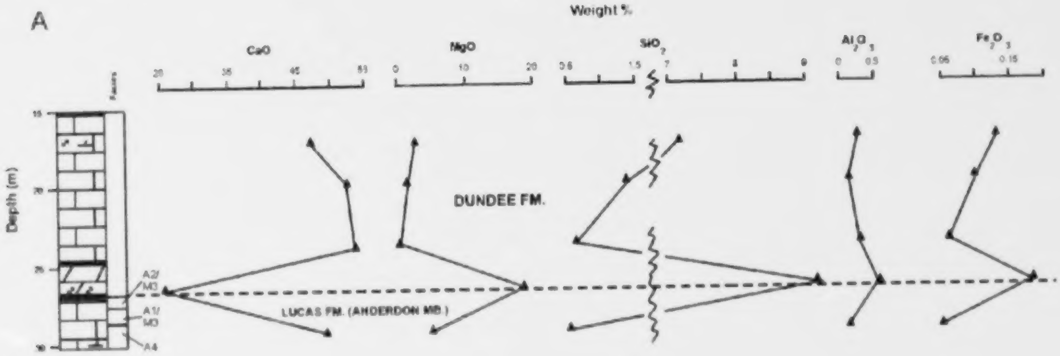


Figure 14. A) Geochemical vertical profiles of Lucas Formation (Cansalt DDH 87-3); and B) Lucas and Dundee formations (Lucas No. 3 – existing data), Essex County; triangles represent data *from* Kelly (1996).

(#3)
Lucas No. 2 (LU-02)



(#4)
Imperial et al. 813 (IMPR)

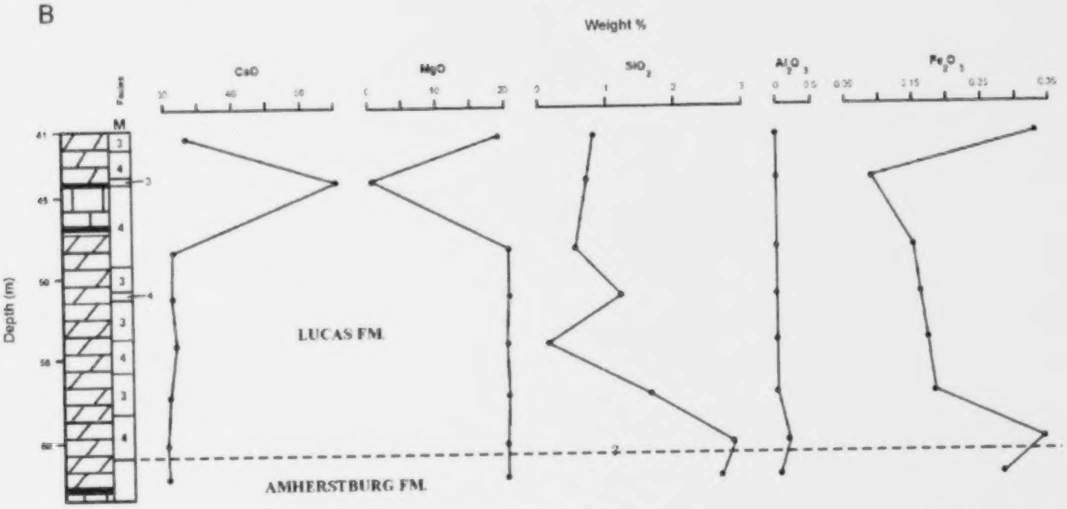
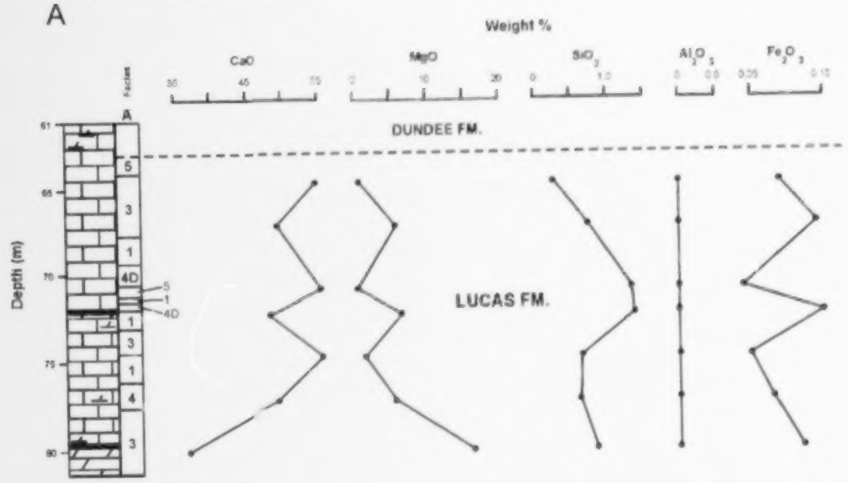


Figure 15. A) Geochemical vertical profiles of Lucas and Dundee formations (Lucas No. 2 – existing data) (triangles represent data *from* Kelly (1996)); and B) Amherstburg and Lucas formations (Imperial et al. 813), Essex County.

(#5)
Consolidated West CT-1 (CWT)



(#6)
Consumers 33409 (CON3)

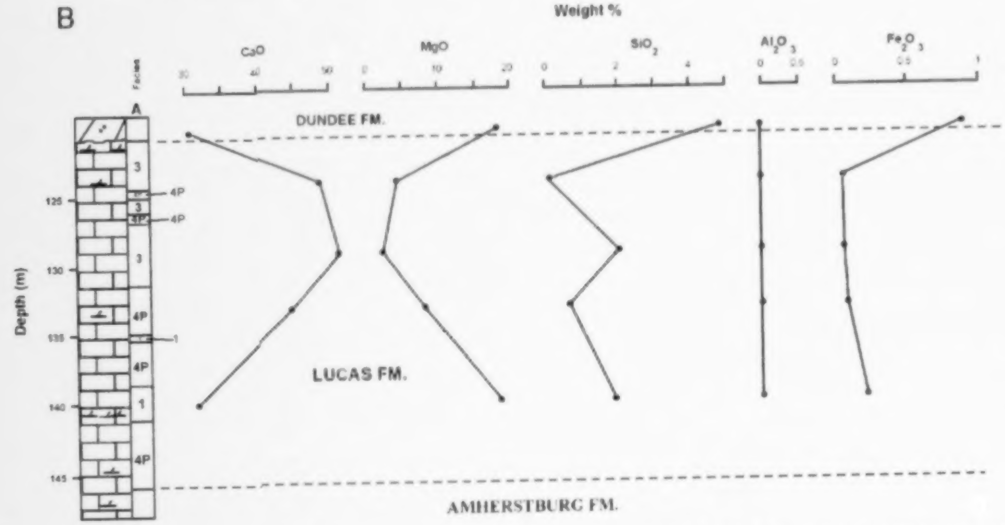


Figure 16. A) Geochemical vertical profiles of Lucas Formation (Consolidated West CT-1, Lake Erie); and B) Lucas and Dundee formations (Consumers 33409, Kent County).

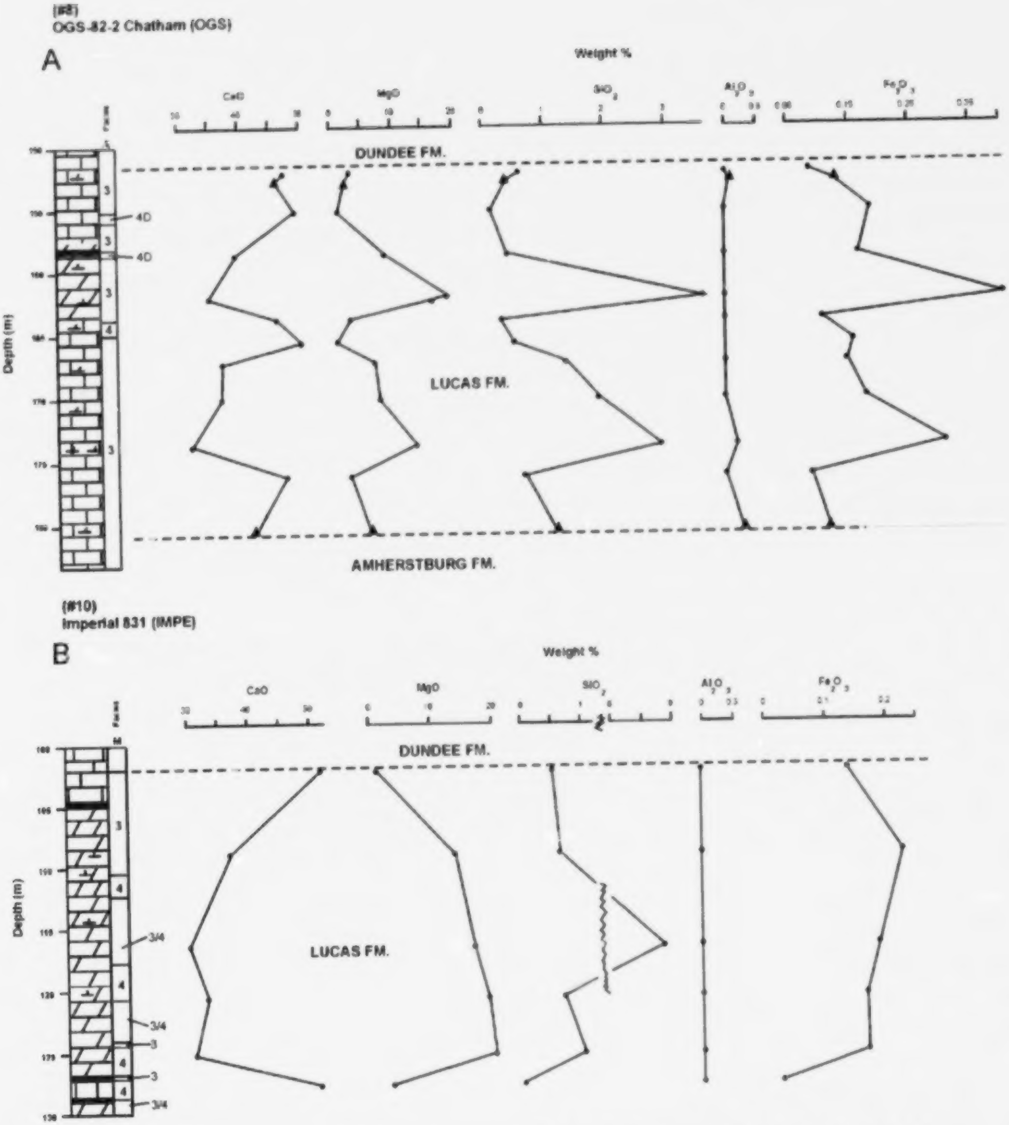


Figure 17. A) Geochemical vertical profiles of Lucas Formation (OGS-82-2 Chatham) in Kent County (triangles at top and bottom of profiles represent data *from* Kelly (1996), drill holes 90-OGS-1 and 90-OGS-2, respectively); and B) Lucas Formation (Imperial 831) in Lambton County.

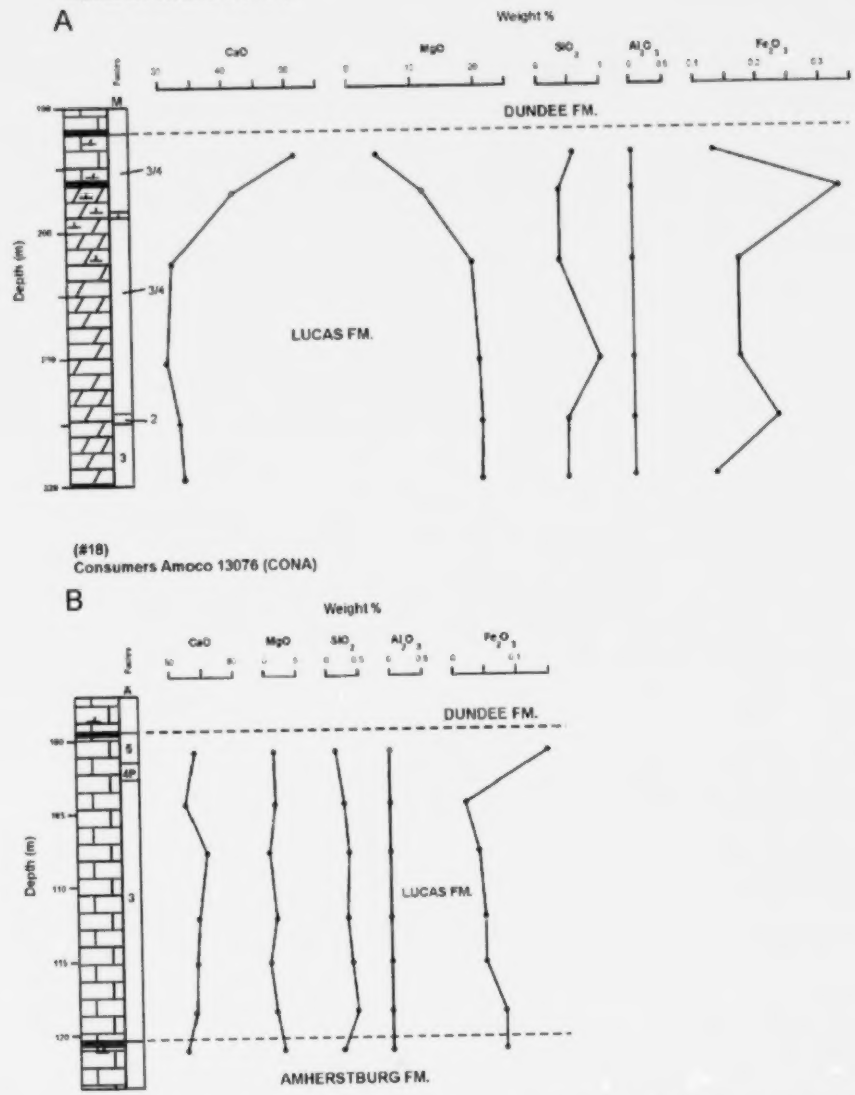
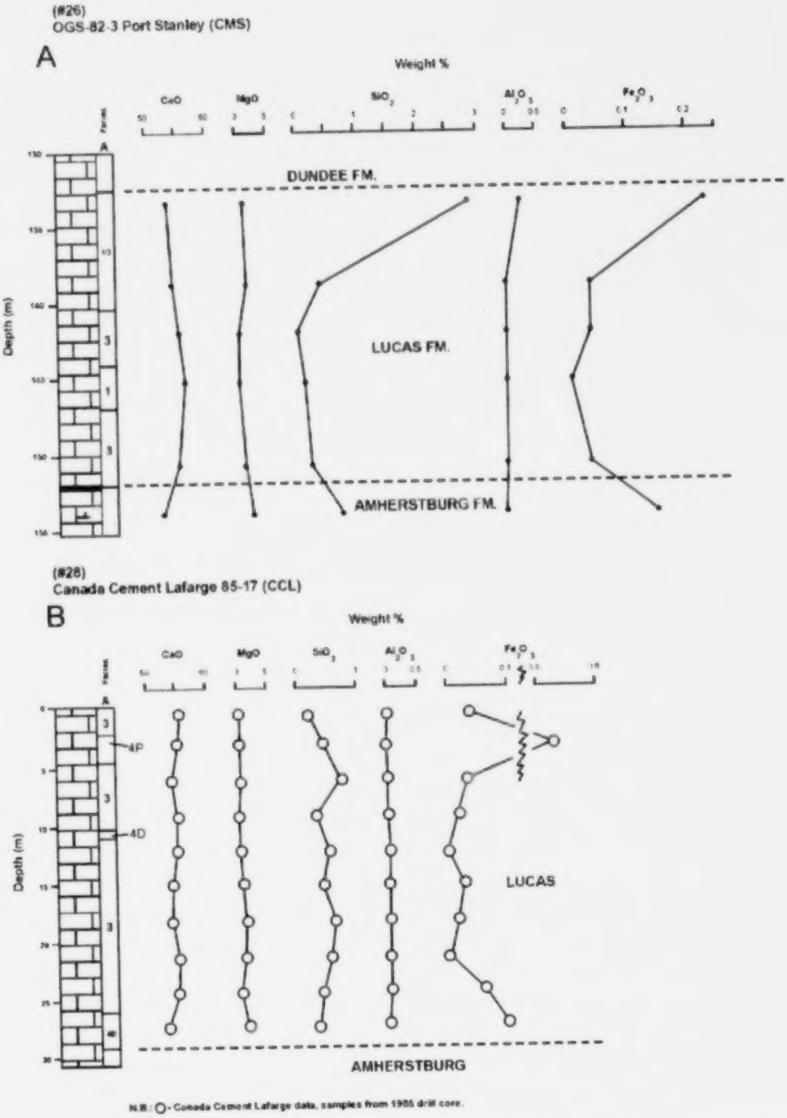


Figure 18. A) Geochemical vertical profiles of Lucas Formation (Imperial 661 Corunna 18) in Lambton County; and B) Amherstburg and Lucas formations (Consumers Amoco 13076) in Elgin County.


(#26) OGS-82-3 Port Stanley (CMS)

(#28) Canada Cement Lafarge 85-17 (CCL)

N.B.: ○ - Canada Cement Lafarge data, samples from 1985 drill core.

Figure 19. A) Geochemical vertical profiles of Amherstburg and Lucas formations (OGS-82-3) in Elgin County; and B) Lucas Formation (Canada Cement Lafarge 85-17 – existing data) in Elgin County.

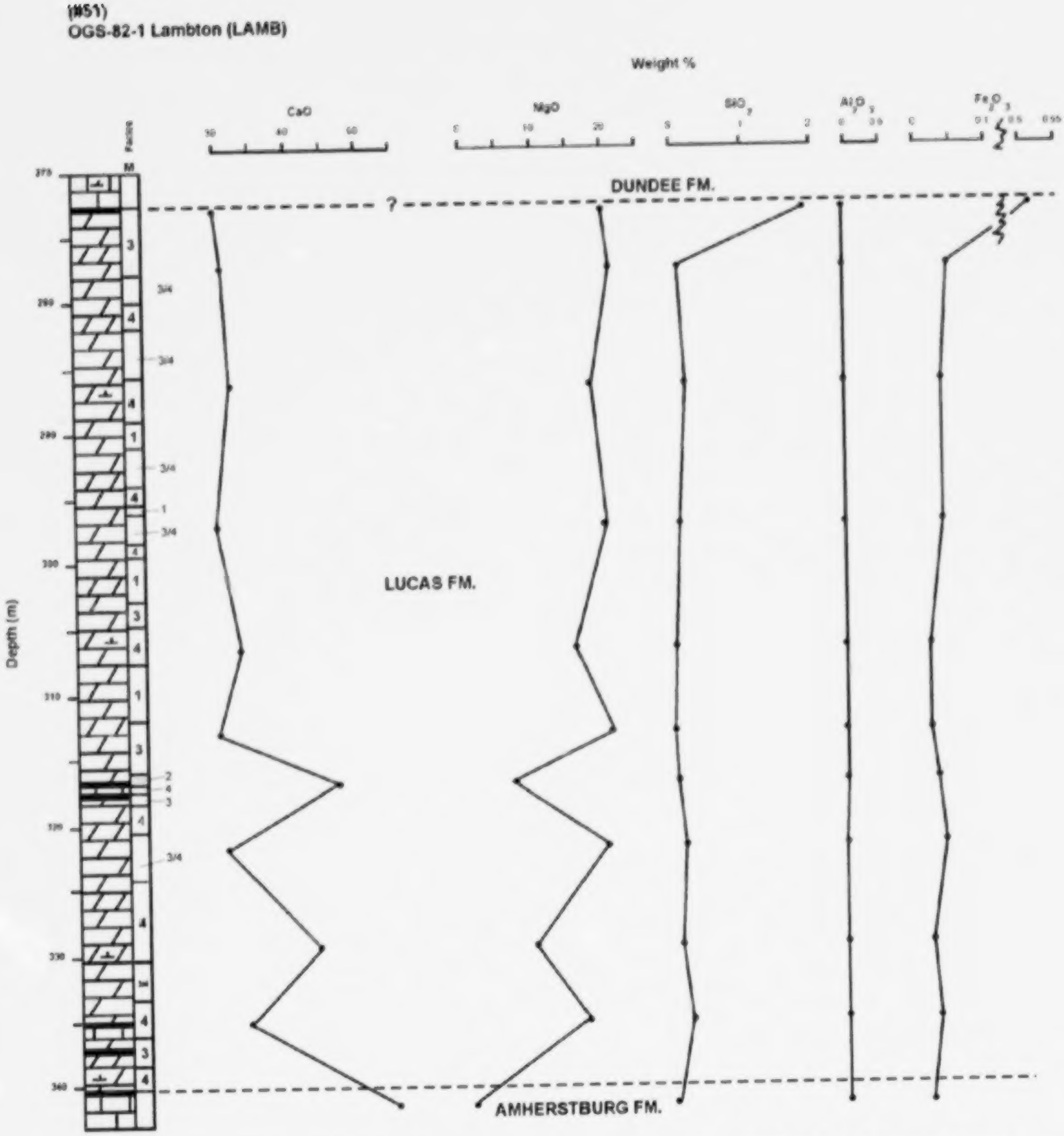


Figure 20. Geochemical vertical profile of Amherstburg and Lucas formations (OGS-82-1) in Lambton County.

Discussion of Results

Throughout the text, as a means of summarizing the various sets of data, the median value, as opposed to the mean or mode, is referred to. The median seems to be the best measure of central tendency of the various distributions and is not as easily affected by extreme values, as is the case with the mean, or by class interval size, as with the mode.

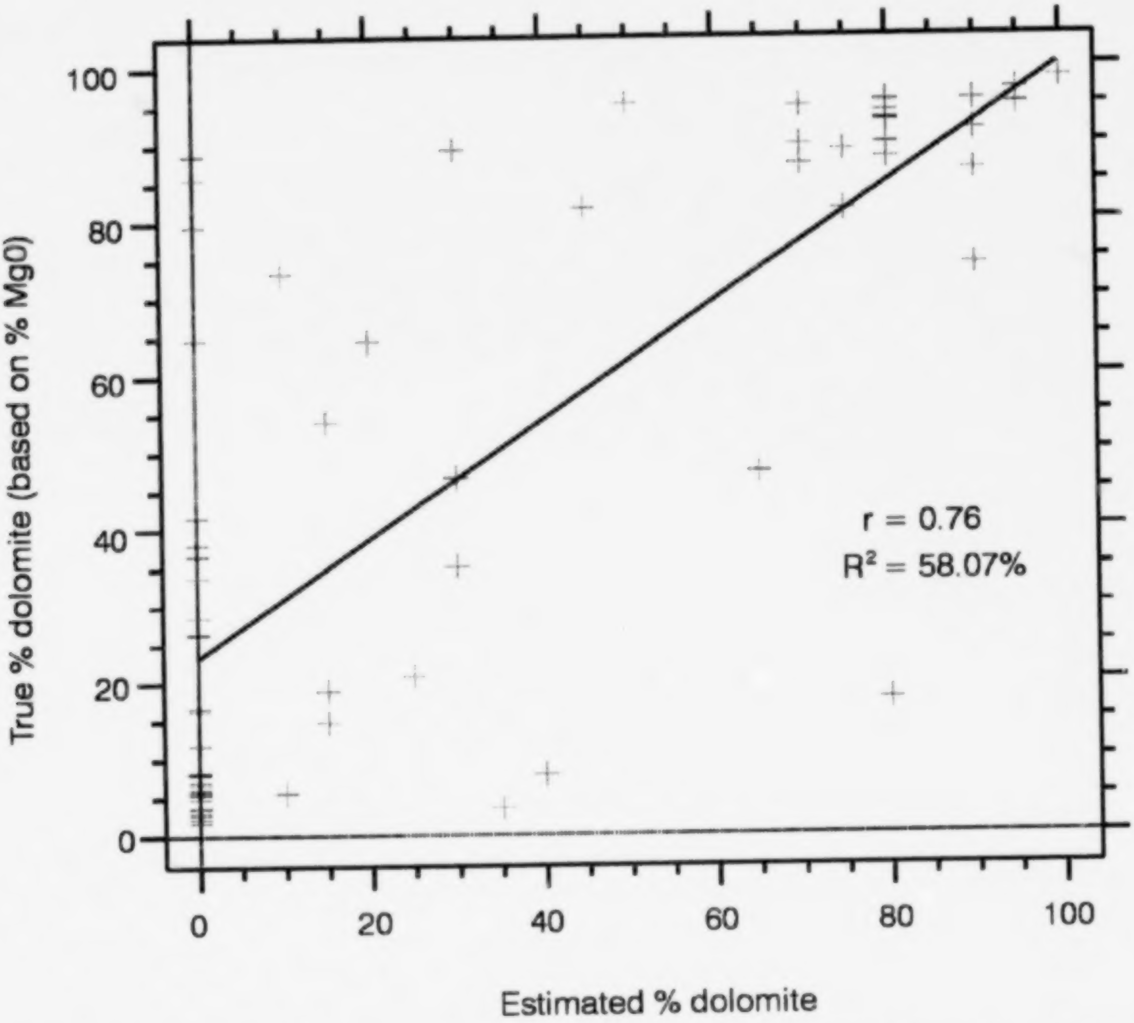


Figure 21. Scatter plot showing fair to good relationship between estimated degree of dolomitization of sampled intervals as determined from core examination, and actual degree of dolomitization based upon MgO content.

Table 4. Limestone and dolostone classification distribution of all Lucas Formation samples (n = 66) based on MgO content. Limestone and dolostone classification *after* Hewitt and Vos (1972).

Classification	% MgO	Number of Samples
High-purity limestone	0 – 1.1%	8
Magnesian limestone	1.1 – 2.1%	10
Dolomitic limestone	2.1 – 10.8%	17
Calcitic dolostone	10.8 – 19.5%	14
High purity dolostone	19.5 – 21.6%	17

ACCURACY OF DOLOMITIZATION ESTIMATION

Geochemical analysis of the Lucas Formation conveniently allows for a check of the "true" dolomite content (based on weight MgO content) of sampled intervals against visual estimates of the same intervals done in the core laboratory with the aid of a binocular microscope, hydrochloric acid (HCl) and Alizarin Red S solution. Visual estimates, in general, are fairly accurate and adequate for most descriptive purposes, but may be thrown off by high porosity and/or permeability and by the presence of significant amounts of oil staining in the rock, as was observed in many of the Lucas Formation cores. One problem in comparing the 2 sets of values is the highly localized nature of dolomitization within the Lucas Formation, sometimes exhibiting considerable variation even within a single lithofacies unit. Due to time constraints on the logging of core, visual estimates were at times done quickly and the value reported may represent an average for an entire unit interval. On the other hand, the "true" value based on geochemical results (MgO content) represents a mere 6 cm interval and may not be truly representative of the interval from which it came.

Although the scatter plot of "true" dolomite content (based on MgO content) versus estimated dolomite content shows considerable scatter (Figure 21), it suggests that the accuracy of the visual estimation of the degree of dolomitization in this study was fair to good. The data suggest that a correlation between the 2 variables (test statistic, *t*, is significant at the 95% level), although not strong, with $r = 0.76$ and $R^2 = 58.07\%$, does exist (*see* Figure 21). Porosity, permeability and oil staining also probably influenced the estimations of the degree of dolomitization.

GEOCHEMISTRY OF THE LUCAS FORMATION

Regional Geochemical Trends

Appendix K contains histograms that graphically show the Lucas Formation to vary widely with respect to CaO and MgO content. The MgO and CaO contents range from 0.41 to 21.50% and 30.08 to 56.25%, respectively. The bimodal nature of the MgO and CaO frequency distributions reflects the 2 predominant rock types: limestone and dolostone. This distribution pattern emphasizes the need to examine the data with respect to depositional basin (see below). Modes (here referring to the mid-point of the class interval with the greatest number of observations) occur at 1.7% and 19.7% for MgO, and 30.8% and 54.8% for CaO. Table 4 summarizes the general distribution of the samples according to limestone and dolostone classification.

Total impurities ($SiO_2+Fe_2O_3+Al_2O_3$) in the Lucas Formation, of which SiO_2 is the primary component, range from 0.07 to 9.05%, with a mode of 0.3%; generally the amount of impurities is low, with 92% of the samples containing less than 3% impurities. The majority of the samples (94%) have Al_2O_3 contents of 0%; the remaining 6% have Al_2O_3 contents of less than 1%.

Table 5. Percentage of high-purity limestone and dolostone samples that meet various specification limits (*see* Derry Michener Booth and Wahl and OGS (1989a) for more details concerning specification limits). For example, 59% of the high-purity dolostone (i.e., having >19.5% MgO) samples have SiO_2 contents of less than 1.0%, and would probably be suitable for metallurgical purposes. Blanks (–) represent non-applicable limits to any one element.

High-Purity Limestone Samples (n = 8)

	Chemical Requirement Limits (%)										
Element(s)	**<0.01**	**<0.02**	**<0.06**	**<0.1**	**<0.5**	**<1.0**	**<2.0**	**<3.0**	**42-44**	**45-47**	**>49**
CaO+MgO	–	–	–	–	–	–	–	–	–	–	100
SiO_2	–	–	–	–	75	88	100	–	–	–	–
Fe_2O_3	–	–	75	100	100	100	–	–	–	–	–
Al_2O_3	–	–	–	–	100	100	–	–	–	–	–
$Al_2O_3+Fe_2O_3$	–	–	–	–	100	100	–	–	–	–	–
$SiO_2+Al_2O_3+Fe_2O_3$	–	–	–	–	–	–	–	100	–	–	–
P_2O_5	100	100	–	100	–	–	–	–	–	–	–
LOI	–		–	–	–	–	–	–	100		–

High-Purity Dolostone Samples (n = 17)

	Chemical Requirement Limits (%)										
Element(s)	**<0.01**	**<0.02**	**<0.06**	**<0.1**	**<0.5**	**<1.0**	**<2.0**	**<3.0**	**42-44**	**45-47**	**>49**
CaO+MgO	–	–	–	–	–	–	–	–	–	–	100
SiO_2	–	–	–	–	41	59	88	–	–	–	–
Fe_2O_3	–	–	24	29	94	100	–	–	–	–	–
Al_2O_3	–	–	–	–	100	100	–	–	–	–	–
$Al_2O_3+Fe_2O_3$	–	–	–	–	94	100	–	–	–	–	–
$SiO_2+Al_2O_3+Fe_2O_3$	–	–	–	–	–	–	82	94	–	–	–
P_2O_5	100	100	–	100	–	–	–	–	–	–	–
LOI	–	–	–	–	–	–	–	–	–	71	–

Six samples, mostly dolostones, yielded slightly low totals (93.21 to 97.96%). The low totals of samples LAMB 4 and LAMB 8, from the OGS-82-1 drill hole, are probably due to the presence of sulphates, most likely anhydrite, whereas those for the remaining samples may be due to instrumental variations on high MgO and CaO contents.

Most of the trace elements were found to be present in amounts less than 5 ppm. All the Cansalt DDH 87-3 (CNS) drill hole samples had high chromium (21 to 57 ppm Cr), and samples from the Consolidated West CT-1 and Imperial 831 drill holes (CWT and IMPE, respectively) had relatively high zinc concentrations (7 to 31 ppm Zn). Of interest, particularly as they may be indicative of Mississippi Valley-type mineralization, are the extremely high zinc concentrations recorded for 2 of the Amherstburg Formation samples: 1183 ppm Zn and 2671 ppm Zn for CONA-7 (Consumers Amoco 13076) and LAMB-16, respectively. Cores OGS-7 (OGS-82-2) and CNS-5 both had high copper, 936 ppm Cu and 53 ppm Cu, respectively. Copper concentrations for samples analyzed in February 1993 (i.e., CWT, IMPE, CMS, LAMB) were somewhat higher (6 to 18 ppm) than those (i.e., CNS, CON3, CONA, IMPC, IMPR, OGS) analyzed earlier (generally less than 5 ppm) (*see* Table 3 for the sample name abbreviations for the drill holes). These higher levels are either real or may be a function of analytical variation.

Most of the Lucas Formation high-purity limestone and dolostone samples are suitable for a wide variety of industrial uses. Suitability of these samples for various chemical purposes are listed in Table 5. The reader is referred to Derry Michener Booth and Wahl and OGS (1989a) and Harben (1999) for details concerning the specification limits cited here.

Interbasinal Geochemical Trends

Of the various elements analyzed, only CaO and MgO contents exhibit marked differences between the 2 basins, reflecting the different carbonate regimes. The MgO content of samples obtained from both basins showed similar ranges (e.g., 0.41 to 19.41% for the Appalachian Basin, and 0.78 to 21.5% for the Michigan Basin). However, the distribution of values for the Appalachian Basin are positively skewed (median of 2.21%), whereas those for the Michigan Basin are negatively skewed (median of 19.94%). Based on MgO content, 22% of the Appalachian Basin samples classify as high-purity limestone (MgO <1.1%), 28% as magnesian limestone (1.1 to 2.1% MgO), 38% as dolomitic limestone (2.1 to 10.8%), 13% as calcitic dolostone (10.8 to 19.5%), and none as high-purity dolostone (MgO >19.5%). Of the Michigan Basin samples, 50% classify as high-purity dolostone; 29% as calcitic dolostone, 15% as dolomitic limestone, 3% as magnesian limestone, and 3% as high-purity limestone. Thus, the majority of the samples (79%) are dolostones. The CaO values are similarly, but oppositely, distributed: Appalachian Basin samples had a negatively skewed distribution of values, ranging from 31.56 to 56.25% CaO, with a median of 52.63%, and Michigan Basin samples had a positively skewed distribution of values, ranging from 30.08 to 55.37% CaO, with a median of 32.52%.

Total carbonate (MgO+CaO) content seems to be slightly greater in the Appalachian Basin (slightly negatively skewed distribution; median = 55.04%) than in the Michigan Basin (slightly positively skewed distribution; median = 51.89%).

Lucas Formation Facies

Selected histograms and summary statistics for lithofacies geochemical data are presented in Appendix K. Table 6 shows the distribution of lithofacies samples according to limestone and dolostone classifications.

APPALACHIAN BASIN LITHOFACIES

A1 Facies

The 6 samples analyzed from the A1 (supratidal to intertidal) facies had MgO contents ranging from a low of 0.5% to a high of 18.73%; however, the majority of the samples had MgO contents less than 2.1%, the median being 1.55% (~7% dolomite). The CaO content ranged from 31.56 to 56.25% with the median at 53.72%. Total carbonate (MgO+CaO) of the samples ranged from 50.29 to 56.75% (median 55.20%). The amount of total impurities was low, ranging from 0.15 to 3.35% (median of 1.12%). Of this total, silica had a median of 1.02%; iron oxide, 0.1%; and alumina, 0%. No anomalously high levels of the 5 trace elements analyzed for were detected in any of the A1 facies samples. Only zinc and copper occurred at slightly high levels, ranging from 5 to 16 ppm Zn, and less than 5 to 13 ppm Cu.

Of the 6 samples analyzed, only one (CMS-4) can be classified as a high-purity limestone (*see* Table 6). Impurities in this sample totalled 0.15% (0.14% SiO_2, 0.01% Fe_2O_3, 0% Al_2O_3).

Table 6. Distribution of lithofacies samples according to limestone and dolostone classification based on MgO content (Hewitt and Vos 1972; *see also* Table 2 "Classification #2"). Percentages have been rounded off and may not total 100%.

		Percentage of Samples				
Facies	**n**	**High-Purity Limestone**	**Magnesian Limestone**	**Dolomitic Limestone**	**Calcitic Dolostone**	**High-Purity Dolostone**
A1	6	17%	50%	17%	17%	0%
A3	22	23%	27%	36%	14%	0%
A4	4	0%	25%	75%	0%	0%
A5	2	50%	50%	0%	0%	0%
M3	22	0%	5%	9%	27%	59%
M4	22	5%	0%	18%	36%	41%

A3 Facies

Twenty-two samples were analyzed from the Appalachian subtidal facies, which is considered to have the best potential for producing high-purity limestone in the Lucas Formation. Histograms (*see* Appendix K) of the A3 facies geochemical data show the MgO and CaO values to be asymmetrically distributed: positively skewed for the former and negatively skewed for the latter. The MgO contents ranged from 0.61 to 19.41%, with a median of 2.21% (about 10% dolomite). Based on percent MgO, 86% of the samples analyzed can be classified as limestones, 26% of which are high purity. The CaO content in the facies varies similarly, ranging from 36.65 to 55.81%, the median being 52.63% (~93.93% $CaCO_3$). Total carbonate (MgO+CaO) values have a slightly negatively skewed distribution; the median is 55.00%, with values ranging from 49.85 to 59.62%. Of the samples classified as high-purity limestone, all had total impurities of less than 0.5%, with an average of 0.3% and would be considered chemical grade. Trace element values in the samples of this facies are relatively unremarkable. A few exceptions include high copper (936 ppm Cu) in one sample (OGS-7); relatively high zinc in CWT samples (12 to 31 ppm Zn); high copper in CWT (6 to 17 ppm Cu) and in CMS (11 to 15 ppm Cu) samples.

A4 Facies

Only 4 samples were analyzed from the A4 (biostromal) facies. The limited geochemical data show a relatively narrow range with respect to MgO and CaO contents. Samples from this facies contained between 1.72 to 8.32% MgO and 44.87 to 54.48% CaO; averages, which, in this case, were similar to the medians of 4.85% MgO and 49.99% CaO. Total carbonate averaged 54.84% and ranged from 53.19 to 56.20%. The amount of total impurities in the samples was low (0.56% average), ranging from 0.37 to 0.74%. Of this total, silica averaged 0.44%; iron oxide, 0.12%; and alumina, 0%. Only 2 samples were sent for trace element analysis; CWT-6 had relatively high zinc (16 ppm Zn) and copper (11 ppm Cu) levels. The majority of the A4 facies samples classify as dolomitic limestone (*see* Table 6). None are high purity.

A5 Facies

The 2 samples analyzed from Appalachian Basin restricted lagoonal facies had MgO and CaO contents less than about 1.5% and greater than 53.5%, respectively. Total impurities were less than 1.5% (<1.4% SiO_2, <0.15% Fe_2O_3 and 0% Al_2O_3). Only 1 (CWT-3) of the 2 samples underwent trace element analysis; this sample, which is a high-purity limestone with 1.36% total impurities, had relatively high lead (96 ppm Pb), zinc (23 ppm Zn) and copper (14 ppm Cu) levels.

MICHIGAN BASIN LITHOFACIES

M3 Facies

From the Michigan Basin supratidal to shallow intertidal facies, 22 samples were submitted for analysis. Ten of these samples came from units assigned to both facies M3 and M4 (i.e., M3/M4). Fifty-nine percent of the samples can be classified as high-purity dolostones having MgO contents exceeding 19.5% MgO. In general, magnesia values for this facies were widely distributed ranging from a low of 1.47 to a high of 21.5%, with a median of 19.66% MgO. The majority of the samples (about 86%) classify as dolostones (68% of these being of high purity); none as high-purity limestones. Total carbonate (MgO+CaO) ranged from 47.73 to 55.18% with a median of 52.15%.

Total impurities in the samples ranged from a low of 0.1% to a rather high 9.05% (sample IMPE-3; with 8.86% silica); however, the majority of the samples (95%) contained less than 3% total impurities (the median value being 0.78%). Silica (generally present in amounts less than 2%), iron oxide, and alumina had medians of 0.61%, 0.16% and 0%, respectively. The high-purity dolostones in this facies all had total impurities of less than 3%; all had iron oxide contents of less than 1.5%, but only 46% of these samples had silica contents of less than 0.5%. Therefore, based on general chemical requirement limits set out by industry, only half are suitable for most industrial uses of high-purity dolostone.

Among the only trace elements displaying elevated levels were zinc and copper. Trace element contents ranged from less than 5 to 16 ppm Zn and less than 5 to 53 ppm Cu; medians were 6 ppm Zn and 8 ppm Cu. High levels of chromium (28 and 21 ppm) were found in 2 of the CNS samples.

M4 Facies

The 22 samples analyzed from the Michigan Basin subtidal facies have a similar range in MgO content as the M3 facies. The MgO values ranged from 0.78 to 21.18%, with a median of 19.08%. Total carbonate (MgO+CaO) content is similar to the M3 facies and had a range of 47.73 to 56.15% and a median of 51.84%. Total impurities had a median of 0.42% ranging from a low of 0.07% to a high of 9.05%. High silica (8.86%) in one of the samples (IMPE-3) accounts for the large range, however, impurities accounted for less than 1.5%. Of the total impurities, silica had a median of 0.31%; iron oxide, 0.08%; and alumina, 0%.

Forty-one percent of the samples from this facies are high-purity dolostones (*see* Table 6) with impurities ranging from 0.1 to 3.32%, but generally less than 1.3%. Seventy-eight percent of these high-purity dolostones have less than 1% each of SiO_2, Al_2O_3 and Fe_2O_3, and would, therefore, be suitable for most metallurgical purposes. The trace elements zinc and copper were present in relatively high levels: zinc ranged from <5 to 14 ppm Zn and copper ranged from less than 5 to 13 ppm Cu, with medians of 6 ppm Zn and 8 ppm Cu. Two CNS samples had high chromium levels of 28 and 57 ppm Cr.

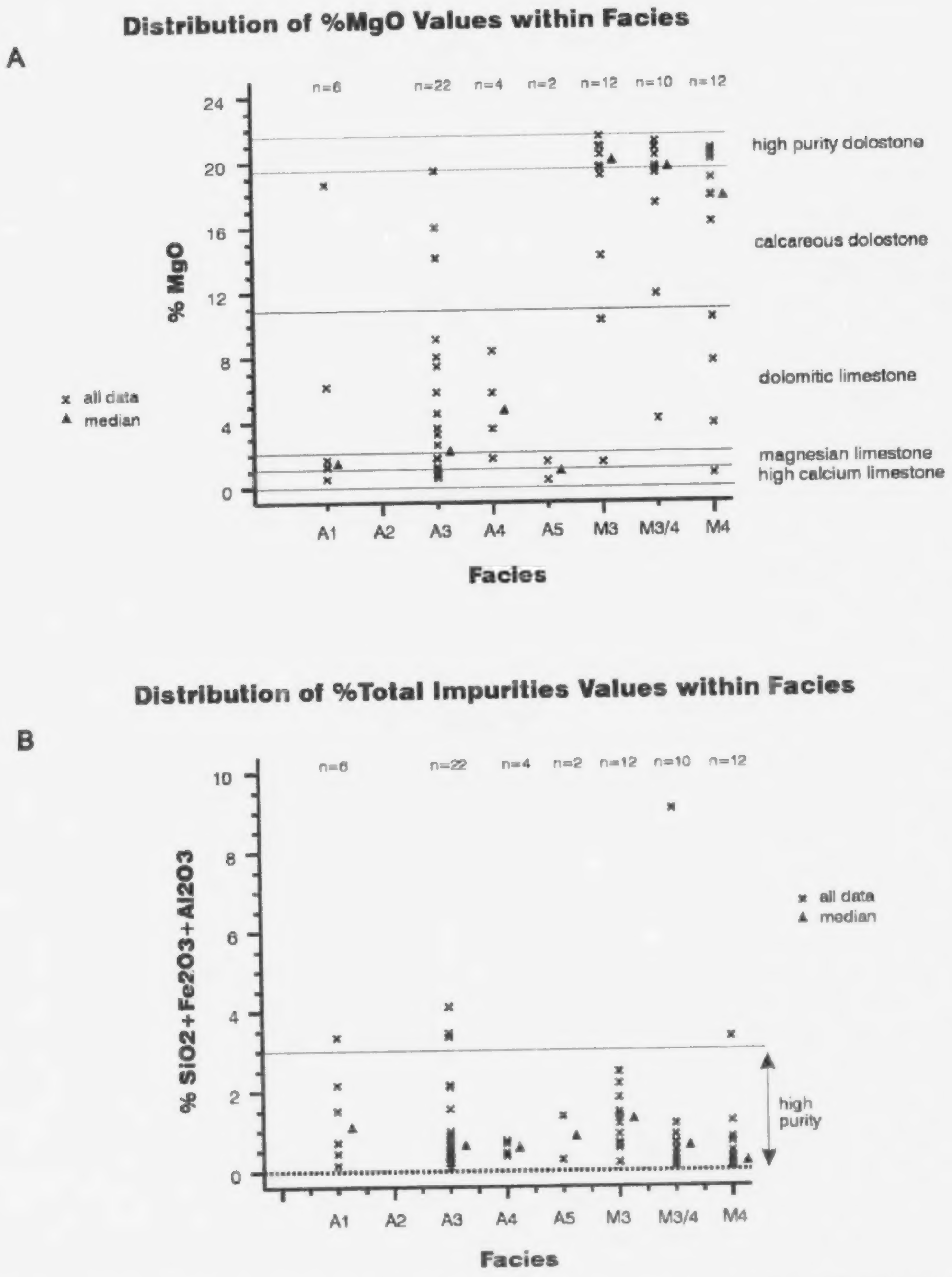


Figure 22. Scatter plot showing A) distribution of % MgO within lithofacies with respect to Appalachian Basin (A1 to A5) and Michigan Basin (M3, M3/4 and M4) lithofacies; and B) % total impurities within lithofacies with respect to Appalachian Basin (A1 to A5) and Michigan Basin (M3, M3/4 and M4) lithofacies.

LITHOFACIES PURITY AND REGIONAL AND VERTICAL TRENDS IN THE LUCAS FORMATION

The main objective of the geochemical portion of this study was to provide a quantitative basis for determining whether there is a correlation between depositional facies and carbonate purity. Results of the lithofacies analysis do suggest a correlation. Some of the factors considered included 1) distance from the basin margin (Algonquin Arch), which, in turn, controlled the distribution and nature of facies within the depositional basins; and 2) the presence of regional-scale faults.

REGIONAL FACIES AND LIMESTONE AND DOLOSTONE PURITY

Results of the geochemical analysis show that the geochemistry of any one lithofacies can vary considerably. These variations are evident both regionally, from drill hole to drill hole, and vertically, within even a single lithofacies interval (e.g., drill holes 1, 8 and 10). Figure 22 shows the relative distribution and central tendencies of the results of the geochemical analyses for MgO and total impurities with respect to Lucas Formation lithofacies. Median values for each lithofacies are also plotted on these graphs. Comparison of corresponding lithofacies histograms (Appendix K) can be done for the other elements not shown. Certain lithofacies in the Appalachian Basin, such as facies A1, A4 and A5, have limited geochemical data making it difficult to compare lithofacies and draw any definite conclusions regarding their geochemistry.

Most of the Lucas Formation lithofacies show similar ranges in values of the different major elements, but the median and clustering of the data points are good indicators of where the differences and similarities lie. With respect to limestone purity in the Appalachian Basin, facies A1, with a median MgO content of 1.55% (~7% dolomite), has, on average, a slightly lower magnesia content than A3 (2.21% MgO, or ~10% dolomite), which, in turn, is lower than A4 (4.68% MgO, or ~21% dolomite). However, this situation is reversed with respect to total impurities and silica content: facies A4, having medians of 0.56% for impurities and 0.47% for silica; facies A3, 0.65% impurities and 0.49% silica; and facies A1, 1.12% impurities and 1.02% silica. Median iron oxide content is the same for all 3 facies, approximately 0.09%.

Facies A3, although quite low in silica and other impurities, actually has lower limestone purity (based on MgO content) than facies A1. If data are included from other drill holes that are not plotted in Figure 22, facies A3 becomes the best potential source of high-purity limestone in the study area. There is an indication of a regional control on the purity of the facies: the degree of dolomitization appears to decrease toward the east. In fact, if the geochemical data from the Canada Cement Lafarge drill hole (drill hole 28; *see* Appendix F; *see* Figure 20) are considered, the calculated overall purity of the A3 facies increases (i.e., median MgO content for facies A3 decreases from 2.21% to 1.28%). The Canada Cement Lafarge quarry in Ingersoll currently extracts high-purity limestone from facies A3 and A4 of the Lucas Formation. The median of alumina, silica and total impurities in this facies remains essentially unaffected, but the iron oxide content decreases from 0.09% to 0.06%. Facies A4 shows a decrease in MgO to 2.66% and increase in total impurities to 0.62%, whereas silica and iron oxide are unchanged. Therefore, with the incorporation of these additional data from a proven high-purity source, facies A3 is shown to be the purest of the Appalachian Basin facies. Additional sampling is required to increase the size of the database of facies A1, A2 and A5 to substantiate this ranking with respect to limestone purity.

The 2 Michigan Basin dolostone facies, M3 and M4, exhibit similar ranges in MgO content (1.47 to 21.5% for facies M3, and 0.78 to 20.7% for facies M4; *see* Figure 22). Lithofacies M3 is, on average, a higher purity dolostone (with median MgO content of 20%) than facies M4 (median MgO content of 17.8%). Lithofacies M3 also possesses nearly 4 times the amount of total impurities (median of 1.23%) than facies M4 (median of 0.3%). However, these conclusions were made without using data from units that were assigned to lithofacies M3/M4 (*see* Figure 22).

Appalachian Basin lithofacies tend to have a slightly higher carbonate content than Michigan Basin lithofacies with an average median of 55.06% compared to 51.90% for the Michigan Basin facies (compare basin histograms in Appendix K).

Vertical Trends in Lucas Formation Geochemistry

A number of scatter plots showing element content versus depth, along with vertical profiles (*see* Figures 14 to 20), were used to examine the variability of the geochemical data with depth. A few vertical trends in the Lucas Formation geochemistry were observed during analysis of the data. Some of these apply basin wide, while others are evident on a local scale at one or a few of the drill cores. These trends are fairly general and based on a limited database. The complex lithofacies relationships of the Lucas Formation would require a much smaller sampling interval than that carried out for this study.

Regional Trends in Lucas Formation Geochemistry

Figures 23 to 25 are cross-sections showing the medians of selected major elements at sampled drill core sites. Apart from demonstrating the obvious gross basinal differences in the degree of dolomitization of the Lucas Formation, these graphs illustrate the more subtle regional geochemical trends occurring within both depositional basins. They complement the lithofacies study by highlighting potential areas of high-purity limestone and dolostone sources.

From Essex County, in the Michigan Basin, eastward to Elgin County, in the Appalachian Basin, (*see* Figure 23), median values of SiO_2 and of total impurities show an overall decrease. Numbers range from approximately 1.3% to approximately 0.3%, with a peak of approximately 1.4% occurring at drill hole 6 in Tilbury East Township. The amount of MgO in the sections shows a similar eastward decrease (from ~19.48% to 1.08%) with a marked jump occurring at the margins of both basins. The increase in limestone purity, based on MgO content, further into the Appalachian Basin is accompanied by decreasing variability in lithology, as indicated by the trend in standard deviation values. Both CaO and MgO+CaO contents increase along this cross-section (*see* Figure 23), again showing a noticeable increase over the Algonquin Arch.

Although fewer drill sites are represented by the northern cross-section (*see* Figure 24: Lambton County to Elgin County), similar regional geochemical trends, particularly with respect to CaO, MgO and MgO+CaO content, are evident. Both CaO and MgO+CaO contents show an overall increase from Moore Township, Lambton County, eastward to Yarmouth Township, Elgin County, with the same marked increase near the vicinity of the Algonquin Arch (between drill holes 10 and 18). The amount of MgO decreases eastward, from a high of 19.79% at drill hole 14, to 15.76% at the edge of the Michigan Basin (drill hole 10), dropping further to 1.08% at drill hole 26, in the Appalachian Basin. An eastward decrease in the amount of impurities is not as pronounced along this cross-section as along the southern one. However, a similar peak in SiO_2 and total impurities does occur in the vicinity of the Algonquin Arch, at drill hole 10.

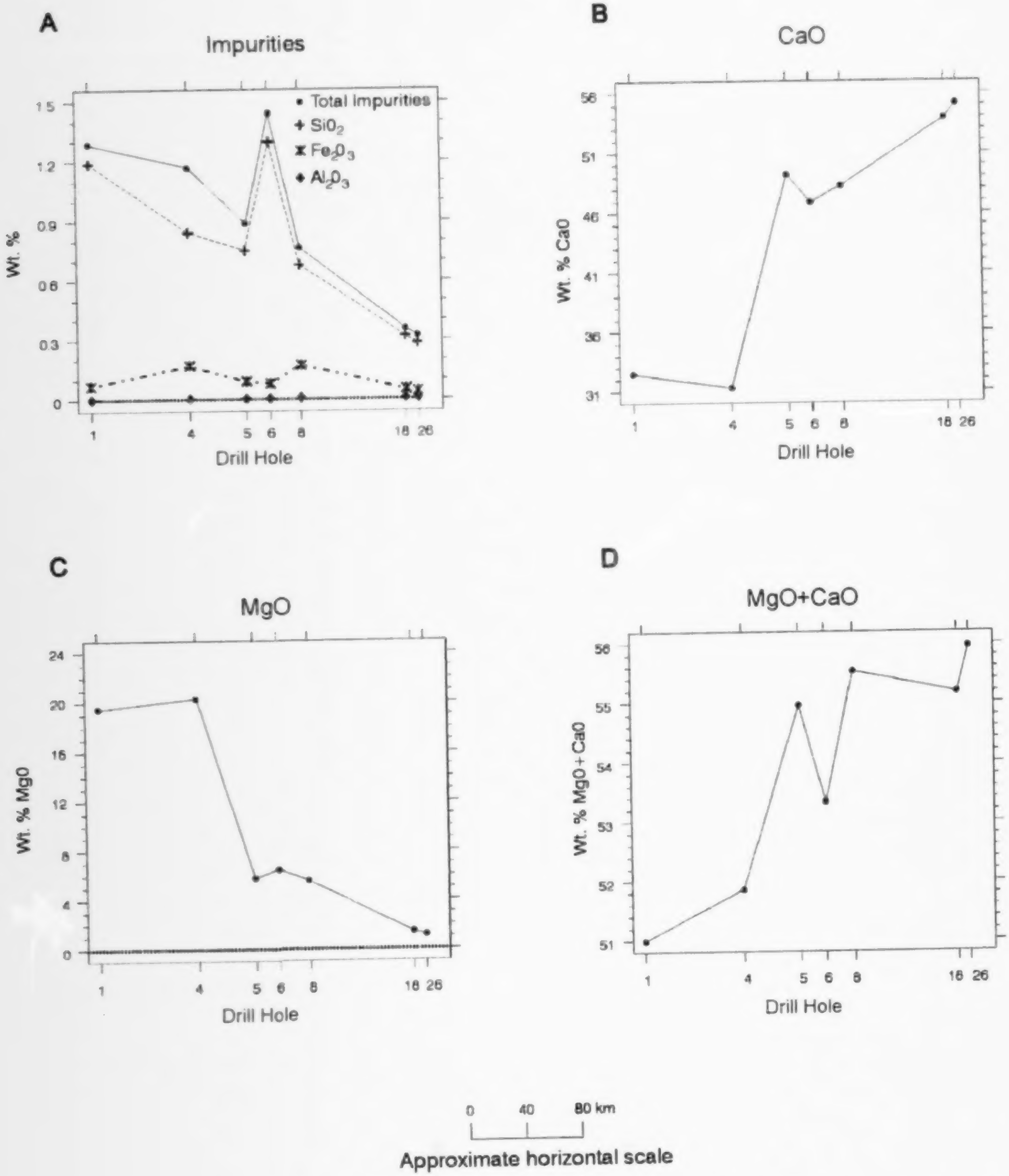


Figure 23. Southern cross-section showing regional variability in the geochemistry of the Lucas Formation from Essex through to Elgin counties: A) total impurities, B) CaO, C) MgO and D) MgO+CaO. For the names and locations of the drill holes, *see* Figure 1.

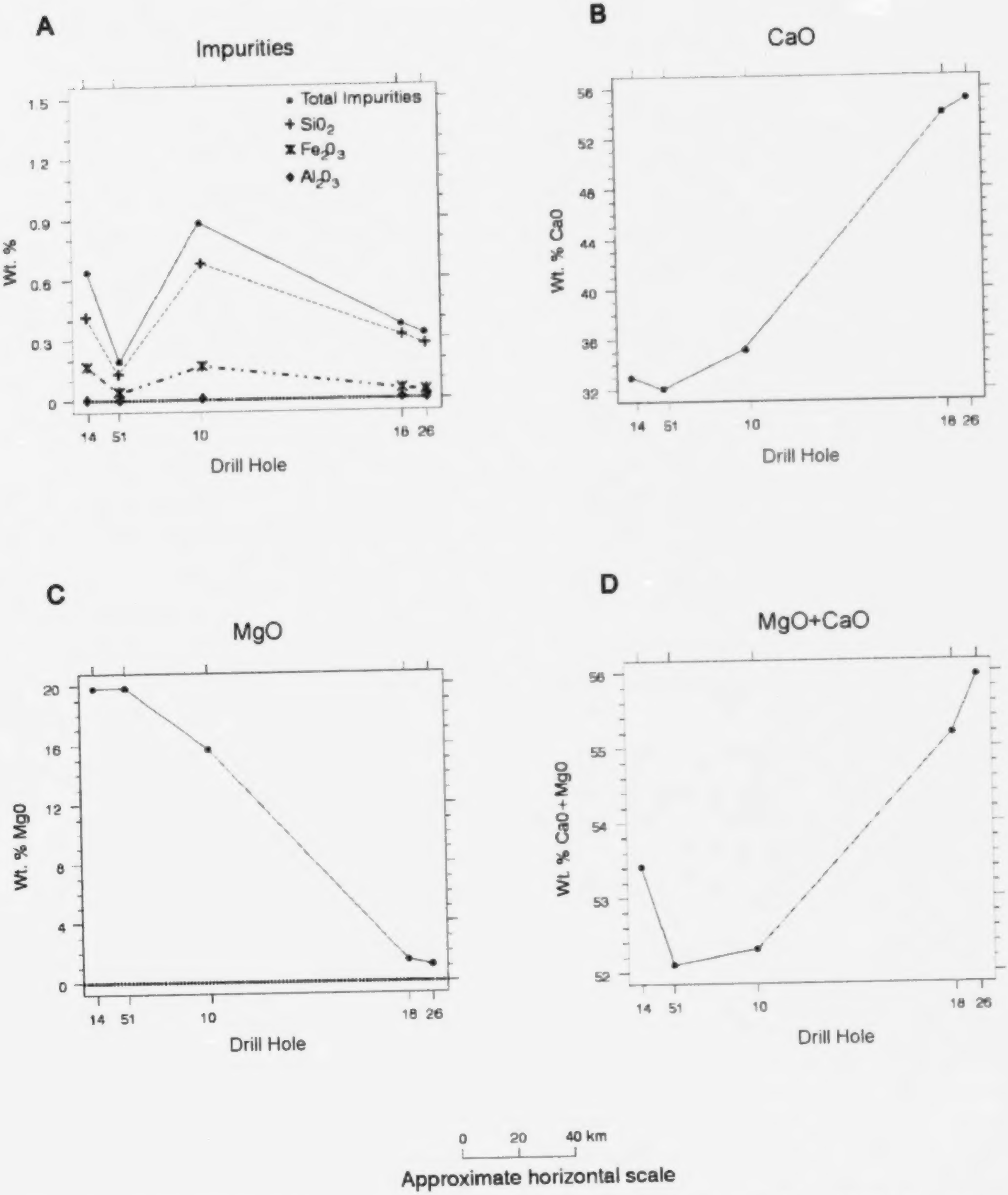


Figure 24. Northern cross-section showing regional variability in the geochemistry of the Lucas Formation from Lambton to Elgin counties: A) total impurities, B) CaO, C) MgO and D) MgO+CaO. For the names and locations of the drill holes, *see* Figure 1.

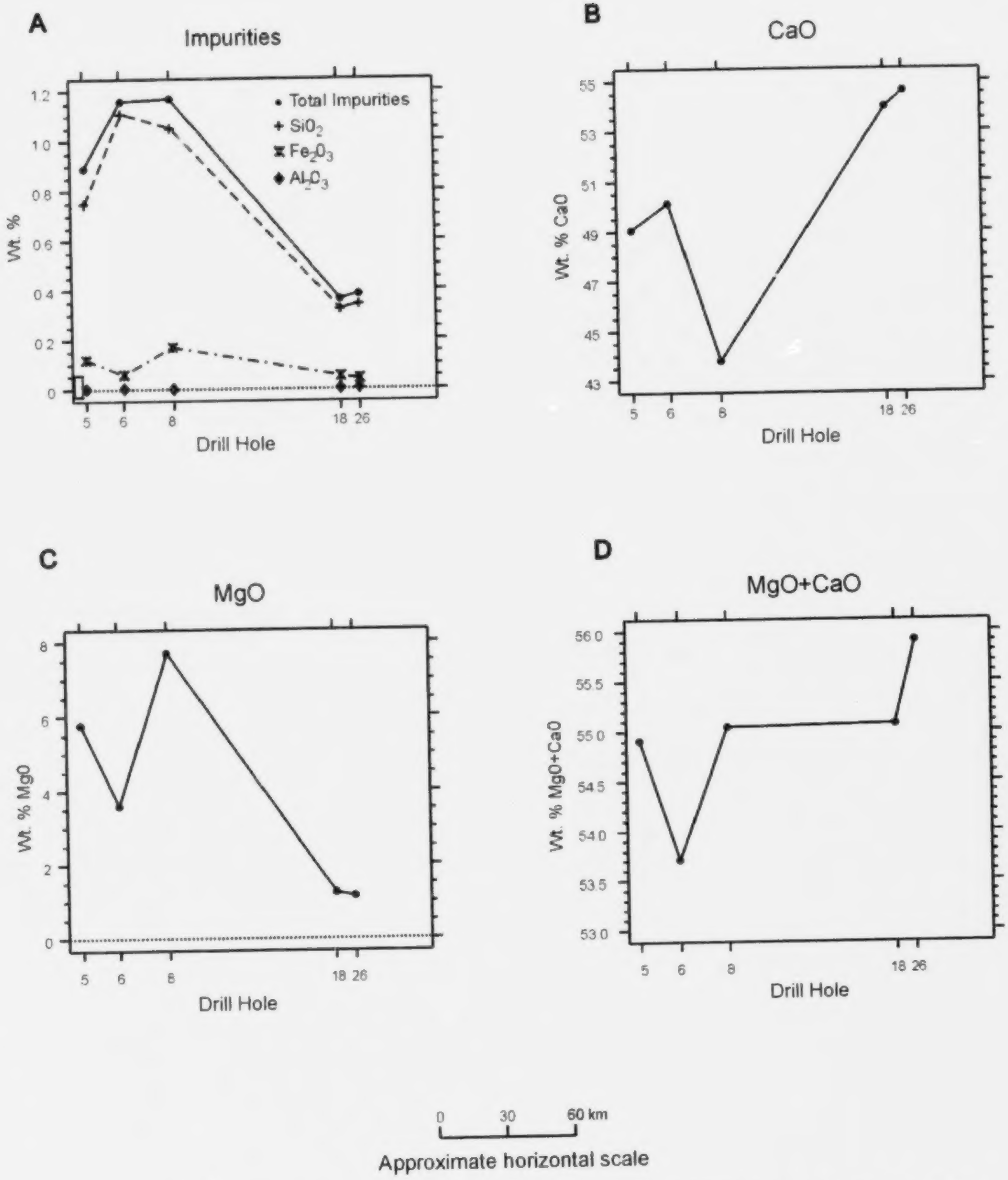


Figure 25. Regional variability in the geochemistry of lithofacies A3, Kent to Elgin counties: A) total impurities, B) CaO, C) MgO and D) MgO+CaO. For the names and locations of the drill holes, *see* Figure 1.

Regional variations in the various elements of facies A3 are depicted as drill hole median values in Figure 25. However, the size of the Appalachian subtidal facies (A3) database is insufficient to make any conclusive statements regarding regional changes in the geochemical character of this facies. As mentioned in early sections, this facies is considered to be the best source for high-purity limestone in the Lucas Formation and is currently being extracted as a high-purity source in the Woodstock–Ingersoll area. Silica and iron oxide content decrease eastward into the Appalachian Basin. Likewise, the amount of MgO in this facies seems to decrease eastward with distance from the basin margin, from a high of 7.7% (dolomitic limestone) at drill hole 8, to a low of 1.14% (essentially high-purity limestone) at drill hole 26. Northeast of drill hole 26, at the Canada Cement Lafarge Quarry, core from drill hole 28 has an even lower median MgO value content of 0.89%. This decrease in magnesia content from drill hole 8 core eastward is accompanied by a decrease in the standard deviation, from a high of 7.81% to a low of 0.47% (0.26% at drill hole 28). The amounts of both CaO and MgO+CaO in this facies increase eastward along with a corresponding decrease in the standard deviation.

CONTROLS ON CARBONATE PURITY IN THE LUCAS FORMATION

Results of the lithofacies and geochemical analysis of the Lucas Formation demonstrate the existence of a regional control on both the distribution and purity of limestone and dolostone. The regional variability of median MgO values is in agreement with the lithofacies analysis: there is an overall shift from high-purity dolostones in the Michigan Basin to increasing limestone purity and decreasing lithological variability within the Appalachian Basin. Although depositional lithofacies likely played a role in controlling the distribution of high-purity zones within the formation, the lack of strong geochemical evidence to support this suggests that other factors, such as basement-controlled structures and hydrothermal fluid migration, may be involved. This study is preliminary in nature, focussing on the depositional lithofacies of the Lucas Formation. Further subsurface work and detailed petrographic and isotopic analyses would be required to examine the extent to which other factors, such as local and regional-scale faults, underlying basement structures, and other structural features and fluid flow pathways, influenced the diagenetic history and nature of dolomitization of the Lucas Formation.

The confinement of Lucas Formation limestone lithologies to the Appalachian Basin, and dolostone lithologies to the Michigan Basin is consistent with the different depositional settings recorded for these 2 basins. The basins were likely separated by the Algonquin Arch during much of the Eifelian, except for possible communication in the area of the Chatham Sag and at an inlet northeast of London (Hamilton 1991; Fagerstrom 1983). Seaways most likely connected the Moose River, "Timiskaming", Michigan and Appalachian basins throughout most of the Ordovician through at least Middle Devonian periods (Prosh and Stearn 1993; McCracken, Armstrong and Bolton 2000). The Appalachian Basin was characterized by deeper, higher energy, more normal marine conditions, with an abundant and diverse faunal assemblage in the Lucas Formation.

The presence of silica in both basins suggests a proximal source for quartz sands: siliciclastics may have originated from the Algonquin and Findlay arches and were shed by eolian processes into both basins. The predominant transport direction appears to have been toward the southeast, into the Appalachian Basin. This direction of wind transport corresponds with prevailing wind and/or current directions suggested by paleogeographic reconstructions (this area of Laurussia would have been approximately 20 to 22°S of the paleoequator; Ziegler 1988, p.21). This latitudinal belt corresponds to present-day southern latitude desert belts of Africa and Australia. The quartz sand source may have been derived from proximal and slightly older Sylvania Formation sandstones or perhaps from siliciclastic units exposed along the Transcontinental Arch, which formed a north-northeast-trending structure throughout much of the central North American craton (Laurussia: Ziegler 1988).

Lucas Formation in the Michigan Basin

In the Michigan Basin of southwestern Ontario, the Lucas Formation is predominantly a microcrystalline to finely crystalline dolostone. Minor interbeds of dolomitic limestone and calcareous dolostone occur in the Chatham Sag area and near the basin margin (southeastern Lambton County). These lithologies are less common further into the Michigan Basin. This basinward decrease in calcareous interlayers is accompanied by an increase in the abundance and thickness of anhydritic dolostone and nodular anhydrite interbeds. The anhydrite layers are generally associated with subtidal to intertidal and supratidal dolostone facies forming a number of shallowing-upward (brining-upward) cycles (up to 7 cycles have been recognized) with the anhydrite layers capping most of the cycles.

The association of dolomites with evaporite deposits is well documented in the literature. Such vertically repetitive carbonate–evaporite cycles as seen in the Lucas Formation, together with the presence of a number of supratidal features, such as microbial laminae, rip-up clasts, mudcracks and evaporite pseudomorphs, is consistent with the evaporitic sabkha model for dolomitization (Tucker and Wright 1990). Melvin (1989) proposed such an origin for the dolostones and evaporites of the Richfield Member of the Lucas Formation in Michigan, a possible correlative of the Lucas Formation of Ontario (Gardner 1974). Hamilton (1990, 1991) examined styles of reservoir development in the Lucas Formation in Ontario. Dolomite fabrics and lithologic associations indicate that both the micritic to very fine crystalline dolomites associated with the dolomitic mudstone lithofacies, and the finely crystalline dolomites associated with the peritidal dolostone sequences, represent penecontemporaneous dolomitization (i.e., dolomitization occurring before or shortly after burial at shallow depths). The former represents sabkha dolomitization and the latter represents shallow subtidal seafloor dolomitization. The medium crystalline dolomites, which are commonly associated with the dolomitic mudstone lithofacies and are found disseminated throughout some of the Lucas Formation limestones, are of deep burial origin (occurring at maximum burial depths of between 440 m and 1.75 km; Hamilton 1991). These volumetrically insignificant dolomites represent minor late-stage dolomitization associated with fluid migration through intercrystalline and intergranular porosity.

The distribution of dolomite within the Michigan Basin Lucas Formation, therefore, appears to be more a function of depositional environment rather than of a burial diagenetic realm. Depositional environment may also explain why the limestone cap found at the top of the Lucas Formation is largely undolomitized. This unit is more fossiliferous than the underlying dolostones and may represent a return to more normal marine environs at the end of the time during which the Lucas Formation was deposited.

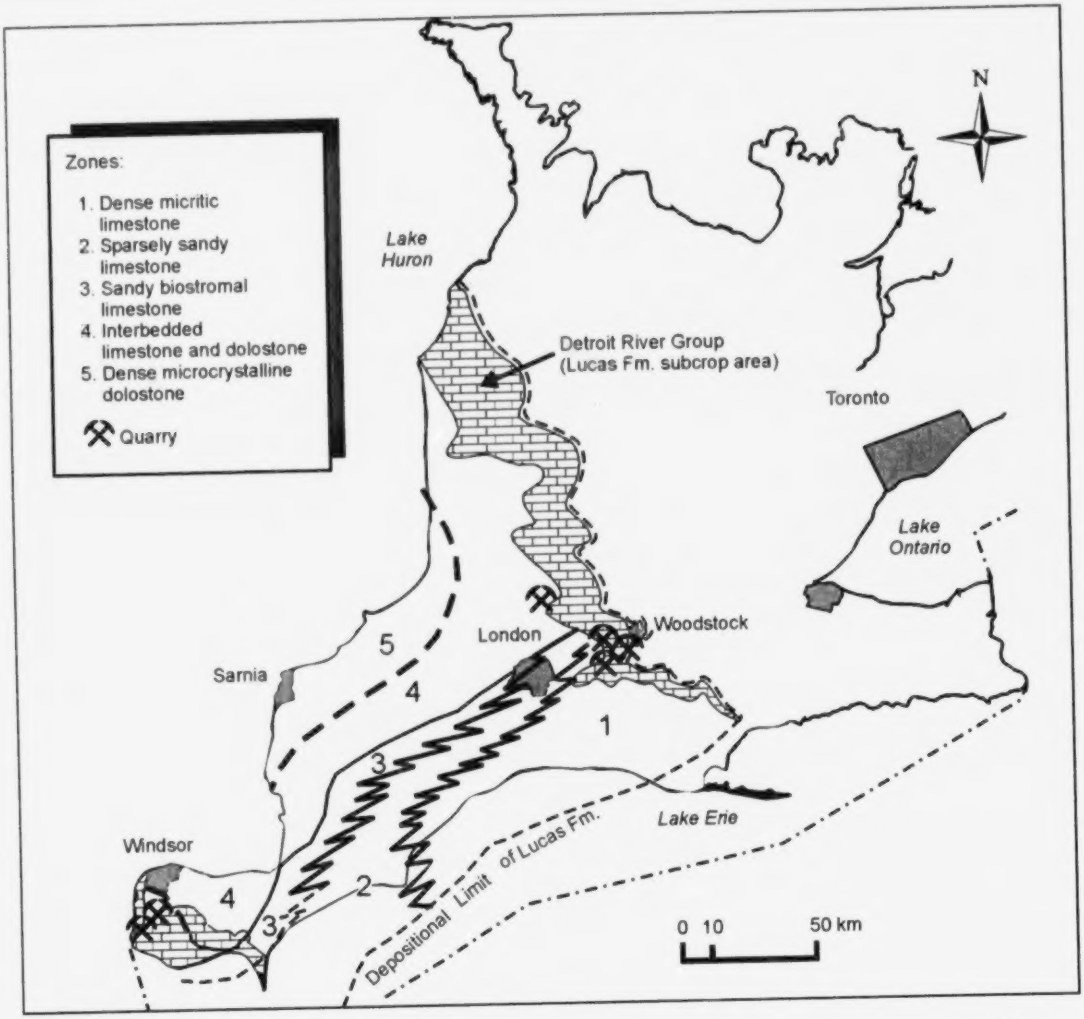

Zones:
1. Dense micritic limestone
2. Sparsely sandy limestone
3. Sandy biostromal limestone
4. Interbedded limestone and dolostone
5. Dense microcrystalline dolostone
Quarry
N
Lake Huron
Detroit River Group (Lucas Fm. subcrop area)
Toronto
Lake Ontario
Woodstock
London
Sarnia
5
4
1
3
Lake Erie
Windsor
4
3
2
Depositional Limit of Lucas Fm.
0 10 50 km

Figure 26. Regional distribution of the 5 diagenetic and/or depositional zones of the Lucas Formation, based upon their carbonate resource potential throughout southwestern Ontario. Exploitation of these resources in parts of southwestern Ontario would require the development of underground aggregate or chemical stone mining operations.

Resource Potential of Lucas Formation Carbonates

The Lucas Formation carbonates in southwestern Ontario can be mapped into 5 diagenetic or depositional zones based upon their resource potential (Figure 26).

1. Zone 1 consists of high-purity, dense, micritic lime mudstones, similar to those quarried in the Woodstock–Ingersoll area of southern Ontario, and are characteristic of Lucas lithofacies in the southeasternmost portions of the study area. This dense, micritic lime mudstone unit is approximately 25 to 30 m thick and can likely be found throughout much of Elgin County, the southern part of Middlesex County and parts of northern Lake Erie. This zone is shown on Figure 26 as the "Dense micritic limestone" zone.

2. Zone 2 comprises approximately 20 to 25 m of fine crystalline, coarse bioclastic limestone, with sparse orthoquartzitic sandstone pulses. Thin biostromal units commonly occur interbedded with thinly bedded dense, microcrystalline and massive, finely crystalline limestones. Dolomite is virtually absent from this unit. This zone is shown on Figure 26 as the "Sparsely sandy limestone" zone.

3. Zone 3 consists of thick orthoquartzitic sandstone and sandy limestone beds interbedded with high-purity limestones, which occur in the upper Lucas Formation within a band that parallels the trend of the Algonquin Arch in parts of Lambton, Middlesex and Kent counties. The presence of silica-rich sands at these localities would tend to limit the high-purity limestone facies in this area to a maximum thickness of 10 to 15 m. This zone is shown on Figure 26 as the "Sandy biostromal limestone" zone.

4. Zone 4 has poor resource potential. The area defined by zone 4 delineates a region of interbedded limestone and dolomite on the southern flank of the Michigan Basin. Both limestone and dolomite lithologies are finely crystalline and generally exhibit fair to poor porosity. This zone is shown on Figure 26 as the "Interbedded limestone and dolostone" zone.

5. Zone 5 consists of dense, microcrystalline to finely crystalline dolomudstones that predominate in the northwesternmost parts of this study area (Lambton County, Sarnia and Plympton townships) and may prove to be a potential source of aggregate. The Lucas Formation in these localities reaches a thickness of approximately 100 m, which includes approximately 75 m of net dolomite, 17 m of net anhydrite and anhydritic dolomite, and approximately 7 to 8 m of a limestone or dolomitic limestone cap at the top of the Lucas Formation. This zone is shown on Figure 26 as the "Dense microcrystalline dolostone" zone.

Summary and Conclusions

The Lucas Formation is a source of high-purity limestone in the Woodstock–Ingersoll and Amherstburg areas of southwestern Ontario. The need for additional resources of this high-purity limestone and to assess subsurface potential for high-purity dolostone, prompted a largely subsurface lithofacies and geochemical study of the Lucas Formation to identify and delineate the high-purity carbonate zones for future extraction.

The Middle Devonian (Eifelian) Lucas Formation is a complex carbonate unit consisting of a variety of depositional and diagenetic lithofacies. The formation consists of 3 distinct, mappable units: 1) finely crystalline, poorly fossiliferous dolostones (undifferentiated Lucas Formation); 2) alternating sparsely fossiliferous, micritic limestones and rudaceous, very fossiliferous skeletal limestone units (Anderdon Member); and 3) thick-bedded, medium-grade, fossiliferous sandy limestones and lenses of orthoquartzitic sandstone (sandy limestone facies of Anderdon Member). The formation is 20 to 40 m thick in the Appalachian Basin and Algonquin Arch areas of southwestern Ontario and thickens westward into the Michigan Basin, reaching a maximum thickness in Ontario of 100 m in Sarnia Township.

Detailed lithological examination of Lucas Formation drill core identified a total of 9 depositional facies; these have been subdivided into 2 basinal systems, reflecting the fact that the Appalachian and Michigan basins were largely separated during the deposition of Lucas Formation and experienced very different depositional environments.

The Lucas Formation of the Michigan Basin consists of 4 depositional facies: upper sabkha mud flat, lower sabkha mud flat, shallow intertidal to supratidal, and subtidal facies. The formation is predominantly dolostone in this area and is poorly fossiliferous and interbedded with anhydrite layers, which become thicker and more common deeper into the Michigan Basin. Lateral and vertical lithofacies relationships of the Lucas Formation in this basin suggest that deposition occurred in a shallow, low energy, hypersaline environment characterized by extensive sabkha-like tidal flats.

The Lucas Formation of the Appalachian Basin is predominantly a fossiliferous limestone consisting of 5 depositional facies: supratidal to intertidal, marginal marine, subtidal, biostromal and restricted lagoonal facies. Sediment characteristics and lateral and vertical lithofacies relationships suggest that deposition occurred in a higher energy, deeper, more normal marine environment than that which the Michigan Basin experienced. Possible communication between the 2 basins may have taken place in the Chatham Sag area where an interfingering of Appalachian and Michigan basin facies occurs. Distribution of the orthoquartzitic sandstones and sandy limestones and their proximity to the Findlay–Algonquin Arch suggest that the sands may have been sourced from the arch, or further afield, and that transportation of this siliciclastic material was primarily directed southeastward into the Appalachian Basin.

Based upon the observed lithofacies distribution in the Appalachian Basin, the subtidal facies, from which the high-purity limestone is extracted, is likely to constitute much of the Lucas Formation in parts of Elgin, Kent, Middlesex and Oxford counties.

LIMESTONE AND DOLOSTONE DISTRIBUTION

The Lucas Formation limestones are found primarily in the Appalachian Basin and the dolostones, in the Michigan Basin with the area of the Algonquin Arch marking the gross limestone–dolostone facies boundary. Interbedded limestones and dolostones occur in the area of the arch in Essex and southeastern Lambton counties. The change from predominantly dolostone lithologies in Enniskillen Township to limestone lithologies in Dawn Township may be related to the nearby, easterly trending Dawn Fault. The fault may delineate the boundary of lateral movement of diagenetic fluids between the 2 basins.

High-purity dolostones are found in deeper parts of the Michigan Basin, but are commonly interbedded with evaporite deposits. A thin, 4 m thick, limestone to dolomitic limestone cap occurs at the top of the Lucas Formation. This unit is more fossiliferous than the underlying high-purity dolostones and may represent a change to more normal marine conditions at the end of Lucas Formation deposition.

High-purity limestones, up to 20 to 30 m in thickness, are located in deeper part of the Appalachian Basin in parts of Kent, Elgin, Middlesex and Oxford counties.

GEOCHEMISTRY OF THE LUCAS FORMATION

Results of the geochemical analysis show the Lucas Formation to vary widely with respect to CaO and MgO content reflecting the 2 predominant rock types—limestones and dolostones—present in the formation. MgO values in the Appalachian Basin are positively skewed, with a median of 2.21% (10% dolomite), while values in the Michigan Basin are negatively skewed, with a median of 19.48% (89% dolomite). Most of the samples contained less than 3% total impurities (silica being the primary component).

Interbasinal geochemical analysis of facies failed to detect any marked differences in the geochemistry of the various facies. Comparison of median MgO values does not show conclusively that the subtidal facies (A3) is the purest of the Appalachian Basin facies, nor that it is, on average, a high-purity limestone. Facies A1 ranks as the purest of the Appalachian Basin facies with respect to MgO content; however, it has nearly twice the total impurities of facies A3, which ranks second. When existing geochemical results from a proven high-purity source are included with this study's data, facies A3 becomes the purest of the Appalachian Basin facies. More sampling is needed to clarify the relationship between depositional facies and carbonate purity.

VERTICAL AND REGIONAL GEOCHEMICAL TRENDS

Comparison of median drill core geochemical values indicates the presence of a few regional trends in the geochemical character of the Lucas Formation. In the Appalachian Basin, there appears to be an eastward (i.e., away from the basin margin) increase in limestone purity (decreasing MgO and total impurities contents) of the Lucas Formation overall and of the A3 facies. (The regional variability in the geochemistry of facies A3 may explain why it did not rank first in facies limestone purity.) In addition, the Lucas Formation becomes more lithologically uniform with depth in this direction. In the Michigan Basin, in Lambton County, a similar basinward increase in dolostone purity (with respect to MgO content) was observed.

RESOURCE POTENTIAL

Based on the results of this study, Lucas Formation carbonates in southwestern Ontario can be mapped into 5 zones based upon their resource potential (*see* Figure 26). In general, high-purity dolostones are likely to be found in the subsurface (on the land portion of Ontario) bordering the southern shore of Lake Huron. Resources of high-purity limestone can be found near the surface or in the subsurface in Elgin and parts of Kent, Middlesex and Oxford counties. The distribution of high-purity limestone in the Appalachian Basin is partly facies controlled, but other factors, such as faults, permeability, subsurface fluid pathways, need to be examined to determine their role in controlling the dolomitization of the Lucas Formation.

Acknowledgments

The material presented in this report is the result of 2 studies pertaining to the facies and carbonate resources (M.C.B.) and the geochemistry (M.A.R.) of the Lucas Formation. The authors would like to thank A. Henry for invaluable assistance in the core lab; P. Smith for word processing support; and D. Schoeffman for unlimited patience in the preparation of the many figures in this report. The authors would also like to thank R. Corcoran for extensive digital redrafting of figures and the transfer of Appendix D into printable format. Sincere thanks are also extended to the staff of the MNR Petroleum Resources Core Laboratory in London for their assistance, and to B. Feenstra, former OGS Resident Geologist for southwestern Ontario region, for insightful and stimulating discussions. Kyle Rhoderick, Chief Geologist for Carmeuse Natural Chemicals North America, provided both information and access to the Anderdon Member lithofacies at their Beachville Lime Quarry near Woodstock, Ontario.

References

Best, E.W. 1953. Pre-Hamilton Devonian stratigraphy, southwestern Ontario, Canada; unpublished PhD thesis, University of Wisconsin, Madison, Wisconsin, 222p.

Birchard, M.C. 1990a. Stratigraphy and facies of the Middle Devonian Dundee Formation, southwestern Ontario; unpublished MSc thesis, McMaster University, Hamilton, Ontario, 136p.

——— 1990b. Stratigraphy and facies of the Middle Devonian Dundee Formation, southwestern Ontario; *in* Subsurface geology of southwestern Ontario: a core workshop, Ontario Petroleum Institute–America Association of Petroleum Geologists, 1990 Eastern Section Meeting, p.131-146.

——— 1993. Stratigraphy and facies of the Middle Devonian Dundee Formation, OGRG 340; Ontario Geological Survey, Open File Report 5848, 156p.

Birchard, M.C. and Risk, M.J. 1990. Stratigraphy of the Middle Devonian Dundee Formation, southwestern Ontario; *in* Geoscience Research Grant Program, Summary of Research 1989–1990, Ontario Geological Survey, Miscellaneous Paper 150, p.71-86.

Bradley, D.C. 1983. Tectonics of the Acadian Orogeny in New England and adjacent Canada; Journal of Geology, v.91, p.381-400.

Brigham, R.J. 1971. Structural geology of southwestern Ontario and southeastern Michigan; Ontario Department of Mines and Northern Affairs, Paper 71-2, 110p.

Carter, T.R. and Easton, R.M. 1990. Extension of Grenville basement beneath southwestern Ontario: lithology and tectonic subdivisions; *in* Subsurface geology of southwestern Ontario: a core workshop, Ontario Petroleum Institute–America Association of Petroleum Geologists, 1990 Eastern Section Meeting, p.9-28.

Carter, T.R. and Trevail, R.A. 1989. Oil and gas exploration, drilling and production summary, 1985; Ministry of Natural Resources, Oil and Gas Paper 8, 212p.

Carter, T.R., Trevail, R.A. and Easton, R.M. 1993. Oil and gas accumulations and basement structures in southern Ontario; 32nd Annual Conference of Ontario Petroleum Institute, Technical Paper 9, 27p.

——— 1996. Basement controls on some hydrocarbon traps in southern Ontario, Canada; *in* Basement and basins of eastern North America, Geological Society of America, Special Paper 308, p.95-107.

Coakley, B.J., Nadon, G.C. and Wang, H.F. 1994. Spatial variations in tectonic subsidence during Tippecanoe I in the Michigan Basin; Basin Research, v.6, p.131-140.

Coniglio, M., Sherlock, R., Williams-Jones, A.E., Middleton, K. and Frape, S.K. 1994. Burial and hydrothermal diagenesis of Ordovician carbonates from the Michigan Basin, Ontario, Canada; *in* Dolomites – a volume in honour of Dolomieu, International Association of Sedimentologists, Special Publication 21, p.231-254.

Coniglio, M., Zheng, Q. and Carter, T.R. 2003. Dolomitization and recrystallization of middle Silurian reefs and platformal carbonates of the Guelph Formation, Michigan Basin, southwestern Ontario; Bulletin of Canadian Petroleum Geology, v.51, p.177-199.

Derry Michener Booth and Wahl and Ontario Geological Survey 1989a. Limestone industries of Ontario, Volume 1. Geology, properties and economics; Ontario Ministry of Natural Resources, Land Management Branch, 158p.

——— 1989b. Limestone industries of Ontario, Volume 3. Limestone industries and resources of central and southwestern Ontario; Ontario Ministry of Natural Resources, Land Management Branch, 175p.

Dunham, R.H. 1962. Classification of carbonate rocks according to depositional texture; *in* Classification of carbonate rocks, American Association of Petroleum Geologists, Memoir 1, p.108-121.

Easton, R.M. and Carter, T.R. 1995. Geology of the Precambrian basement beneath the Paleozoic of southwestern Ontario; *in* Basement Tectonics 10, Proceedings of the Tenth International Conference on Basement Tectonics, Duluth, Minnesota, p.221-264.

Ehlers, G.M. 1950. Revised classification of the Middle Devonian Detroit River Group (abstract); Geological Society of America Bulletin, v.61, p.1455-1456.

Ehlers, G.M. and Stumm E.C. 1951. Middle Devonian Columbus Limestone near Ingersoll, Ontario, Canada; American Association of Petroleum Geologists, Bulletin, v.35, p.1879-1893.

Embry, A.F. and Klovan, J.E. 1971. A Late Devonian reef tract on northeastern Banks Island, Northwest Territory; Bulletin of Canadian Petroleum Geology, v.19, p.730-781.

Ettensohn, F.R. 1985. The Catskill Delta complex and the Acadian Orogeny: a model; Geological Society of America, Special Paper 201, p.39-49.

——— 1994. Tectonic control on formation and cyclicity of major Appalachian unconformities and associated stratigraphic sequences; *in* Tectonic and eustatic controls on sedimentary cycles, SEPM (Society of Sedimentary Geology), Concepts in Sedimentology and Paleontology #4, p.217-242.

Fagerstrom, J.A. 1966. Biostratigraphic significance of rhipidomellid brachiopods in the Detroit River Group; Journal of Paleontology, v.40, p.1236-1238.

——— 1971. Brachiopods of the Detroit River Group (Devonian) from southwestern Ontario and adjacent areas of Michigan and Ohio; Geological Survey of Canada, Bulletin 204, 113p.

——— 1982. Stromatoporoids of the Detroit River Group and adjacent rocks (Devonian) in the vicinity of the Michigan Basin; Geological Survey of Canada, Bulletin 339, 81p.

——— 1983. Petrology and regional significance of a Devonian carbonate/evaporite complex, eastern Michigan Basin; Journal of Sedimentary Petrology, v.53, p.295-317.

Gardner, W.C. 1974. Middle Devonian stratigraphy and depositional environments in the Michigan Basin; Michigan Basin Geological Society, Special Papers No. 1, 138p.

Hamilton, G.D. 1990. Styles of reservoir development in the Middle Devonian of southwestern Ontario; *in* Subsurface geology of southwestern Ontario: a core workshop, Ontario Petroleum Institute–America Association of Petroleum Geologists, 1990 Eastern Section Meeting, p.111-130.

——— 1991. Styles of reservoir development in Middle Devonian carbonates of southwestern Ontario; unpublished MSc thesis, University of Waterloo, Waterloo, Ontario, 191p.

Harben, P.W. 1999. The Industrial Minerals HandyBook, 3rd Edition – a guide to markets, specifications, & prices, Industrial Minerals Information, Ltd. (IMIL), 296p.

Hewitt, D.F. and Vos, M.A. 1972. The limestone industries of Ontario; Ontario Department of Mines, Industrial Minerals Report 39, 79p.

Johnson, A.M. and Sorensen, H.O. 1981. Evaluation of high purity limestone and dolostone in northern Michigan; Geological Society of America Bulletin, v.92, p.634-640.

Johnson, J.G. 1971. Timing and coordination of orogenic, epeirogenic, and eustatic events; Geological Society of America Bulletin, v.82, p.3263-3298.

Johnson, J.G. and Klapper, G. 1992. North American Midcontinent Devonian T–R cycles; *in* Special Papers in Paleontology and Stratigraphy: A tribute to Thomas W. Amsden, Oklahoma Geological Survey, Bulletin 145, p.127-135.

Johnson, M.D., Armstrong, D.K., Sanford, B.V., Telford, P.G. and Rutka, M.A. 1992. Paleozoic and Mesozoic geology of Ontario; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, p.907-1008.

Johnson, M.D., Russell, D.J. and Telford, P.G. 1985. Oil shale assessment project drillholes for regional correlation 1983–84; Ontario Geological Survey, Open File Report 5565, 49p.

Kelly, R.I. 1996. High-purity calcite and dolomite resources of Ontario; Ontario Geological Survey, Open File Report 5954, 38p.

Klapper, G. and Oliver, W.A., Jr. 1995. The Detroit River Group is Middle Devonian: discussion on "Early Devonian age of the Detroit River Group, inferred from Arctic stromatoporoids"; Canadian Journal of Earth Sciences, v.32, p.1070-1073.

Landes, K.E. 1951. Detroit River Group in the Michigan Basin; United States Geological Survey, Circular 133, 23p.

Lane, A.C., Prosser, C.S., Sherzer, W.H. and Grabau, A.W. 1909. Nomenclature and subdivision of the Upper Siluric strata of Michigan, Ohio, and Western New York; Geological Society of America Bulletin, v.19, p.553-556.

Linsley, R.M. 1968. Gastropods of the Middle Devonian Anderdon Limestone; Bulletins of American Paleontology, v.54, no.244, p.333-444.

McCracken, A.D, Armstrong, D.K. and Bolton, T.E. 2000. Conodonts and corals in kimberlite xenoliths confirm a Devonian seaway in central Ontario and Quebec; Canadian Journal of Earth Sciences, v.37, p.1651-1663.

Melvin, J.L. 1989. The Richfield Member of the Lucas Formation of the Detroit River Group (Lower Middle Devonian), Michigan Basin, Michigan, USA; Carbonate and Evaporites, v.4, p.9-43.

Mitrovica, J.X., Beaumont, C. and Jarvis, G.T. 1989. Tilting of continental interiors by the dynamical effects of subduction; Tectonics, v.8, p.1079-1094.

Nisbet, E.G., Dietrich, V.J. and Esenwein, A. 1979. Routine trace element determination in silicate minerals and rocks by X-ray fluorescence; Fortschritte der Mineralogie, v.57, p.264-279.

Norrish, K. and Hutton, J.T. 1969. An accurate x-ray spectrographic method for the analysis of a wide range of geological samples; Geochimica et Cosmochimica Acta, v.33, p.431-453.

Oliver, W.A., Jr. 1981. The Middle Devonian rugose coral *Prismatophyllum conjunctum* (Davis) and the age of the "Columbus" Limestone at Ingersoll, Ontario; Geological Society of America Bulletin, v.92, p.873-877.

Prosh, E. and Stearn, C.W. 1993. Early Devonian age of the Detroit River Group, inferred from Arctic stromatoporoids; Canadian Journal of Earth Sciences, v.30, p.2465-2474.

Pysklywec, R.N. and Mitrovica, J.X. 1997. Mantle avalanches and the dynamic topography of continents; Earth and Planetary Science Letters, v.148, p.447-455.

Quinlan, G.M. and Beaumont, C. 1984. Appalachian thrusting, lithospheric flexure, and the Paleozoic stratigraphy of the eastern interior of North America; Canadian Journal of Earth Sciences, v.21 p.973-996.

Rickard, L.V. 1984. Correlation of the subsurface Lower and Middle Devonian of the Lake Erie region; Geological Society of America, v.95, p.814-828.

——— 1985. Correlation of the subsurface Lower and Middle Devonian of the Lake Erie region: reply; Geological Society of America Bulletin, v.96, p.1218-1220.

Russell, D.J. 1993. Role of the Sylvania Formation in sinkhole development, Essex County; Ontario Geological Survey, Open File Report 5861, 122p.

Sanford, B.V. 1967. Devonian of Ontario and Michigan; *in* International Symposium on the Devonian System, Alberta Society of Petroleum Geologists, Calgary, Alberta, v.1, p.973-999.

——— 1969. Geology, Toronto–Windsor area, Ontario; Geological Survey of Canada, Map 1263A.

Sanford, B.V. and Brady, W.B. 1955. Paleozoic geology of the Windsor–Sarnia area, Ontario; Geological Survey of Canada, Memoir 278, 65p.

Sanford, B.V., Thompson, F.J. and McFall, G.H. 1985. Plate tectonics—a possible controlling mechanism in the development of hydrocarbon traps in southwestern Ontario; Bulletin of Canadian Petroleum Geology, v.33, p.52-71.

Sparling, D.R. 1985. Correlation of the subsurface Lower and Middle Devonian of the Lake Erie region: alternative interpretation; Geological Society of America Bulletin, v.96, p.1213-1218.

Summerson, C.H. and Swann, D.H. 1970. Patterns of Devonian sand on the North American craton and their interpretation; Geological Society of America Bulletin, v.81, p.469-490.

Telford, P.G. and Hamblin, A.P. 1980. Paleozoic geology of the Simcoe area, southern Ontario; Ontario Geological Survey, Preliminary Map P.2234, scale 1:50 000.

Tucker, M.E. and Wright, V.P. 1990. Carbonate sedimentology; Blackwell Scientific Publications, Oxford, United Kingdom, 482p.

Uyeno, T.T., Telford, P.G. and Sanford, B.V. 1982. Devonian conodonts and stratigraphy of southwestern Ontario; Geological Survey of Canada, Bulletin 332, 55p.

Winder, C.G. 1961. Lexicon of Paleozoic names in southwestern Ontario; University of Toronto Press, 161p.

Winder, C.G. and Sanford, B.V. 1972. Stratigraphy and paleontology of the Paleozoic rocks of southern Ontario; XXIV International Geological Congress, Montreal, Quebec, Excursion A45-C45.

Ziegler, P.A. 1988. Laurussia – The Old Red Continent; *in* Devonian of the World, Canadian Society of Petroleum Geologists, Memoir 14, v.1, p.15-48.

Appendix A

List of Drill Holes by Site Number

Appendix A. List of drill holes by site number.

Drill Hole Number (this study)	Drill Hole Name	Township, County
1	Cansalt DDH 87-3, Fighting Is.	Sandwich W. Tp., Essex Co.
2	Lucas No. 3	Anderdon Tp., Essex Co.
3	Lucas No. 2	Colchester S. Tp., Essex Co.
4	Imperial et al. 813, Reimer #1	Gosfield S. Tp., Essex Co.
5	Consolidated West CT-1	Lake Erie
6	Consumers 33409	Tilbury E. Tp., Kent Co.
7	Consumers 33408A	Tilbury E. Tp., Kent Co.
8	OGS-82-2	Harwich Tp., Kent Co.
9	Leesa-Imperial 4-27-XIII	Dawn Tp., Lambton Co.
10	Imperial 831	Enniskillen Tp., Lambton Co.
11	Imperial 838	Enniskillen Tp., Lambton Co.
12	Argor 65-1	Moore Tp., Lambton Co.
13	Imperial 547	Moore Tp., Lambton Co.
14	Imperial 661 Corunna 18	Moore Tp., Lambton Co.
15	M.O.E. Deep Obs. #1	Sarnia Tp., Lambton Co.
16	Lucas No. 1	Mersea Tp., Essex Co.
17	Domtar Test #3	Goderich Tp., Huron Co.
18	Consumers Amoco 13076	Lake Erie
19	Leesa-Imperial 1-13-I	Brooke Tp., Lambton Co.
20	Imperial 700 Ref. 11	Sarnia Tp., Lambton Co.
21	Imperial 809	McGillivray Tp, Middlesex Co.
22	Mitchell #3	Mosa Tp., Middlesex Co.
23	Walker 502	Mosa Tp., Middlesex Co.
24	Allegany Prod. W. 112	Mosa Tp., Middlesex Co.
25	Secord 601	Mosa Tp., Middlesex Co.
26	OGS-82-3	Yarmouth Tp., Elgin Co.
27	Cdnoxy Rodney 5-30	Aldborough Tp., Elgin Co.
28	Canada Cement Lafarge 85-17	West Zorra Tp., Oxford Co.
29	Domtar Beachville 72-5	North Oxford Tp., Oxford Co.
30	Domtar Beachville 72-10	North Oxford Tp., Oxford Co.
33	Cdnoxy Rodney 6-18	Aldborough Tp., Elgin Co.
38	Brett	Camdon Gore Tp., Kent Co.
46	Leesa-Dawn 19-XIII	Dawn Tp., Lambton Co.
51	OGS-82-1	Moore Tp., Lambton Co.
71	Consumers Pan Am 13057	Lake Erie
76	Consolidated West CT-6	Lake Erie
94	Aldborough Oil and Gas #14	Aldborough Tp., Elgin Co.
122	Aldborough Oil and Gas #10	Aldborough Tp., Elgin Co.
143	NYK Oil - Monroe No. 1	Euphemia Tp., Lambton Co.
147	Earl-Bolton No. 1	Metcalfe Tp., Middlesex Co.

Appendix B

List of Drill Cuttings and/or Core Samples Logged for this Study

Appendix B. List of drill cuttings and/or core samples logged for this study.

County and Township	Drill Hole	Lot	Conc.	Core or Tray (T) #	Depth Logged (m)	Drill Hole Number (this study)
Elgin County						
Aldborough Township						
	Aldborough Oil & Gas #10	5	V	4521 (T)	113.1 – 119.8	122
	Aldborough Oil & Gas #14	4	V	5888 (T)	114.0 – 123.1	94
	Cdnoxy Rodney 5-30	5	V	913	111.0 – 120.2	27
	Cdnoxy Rodney 6-18	5	V	947	114.6 – 123.8	33
	Yarmouth Township					
	OGS 82-3	9	I	861	130.0 – 160.0	26
Essex County						
Anderdon Township						
	Lucas No. 3	4	VIII	881	7.6 – 30.6	2
Colchester South Township						
	Lucas No. 2	11	V	882	15.8 – 29.7	3
Gosfield South Township						
	Imperial et al. 813–Reimer # 1	6	IV	197	41.0 – 67.0	4
Mersea Township						
	Lucas No. 1	6	IV	883	20.0 – 32.1	16
Sandwich West Township						
	Cansalt DDH 87-3 Fighting Island			953	32.0 – 62.0	1
Huron County						
Goderich Township						
	Domtar Test #3			764	14.3 – 74.0	17
Kent County						
Camden Gore Township						
	Brett	5	XIV	887	178.9 -185.0	38
Harwich Township						
	OGS 82-2	25	IECR	860	150.0 – 210.0	8
Tilbury East Township						
	Consumers 33408A	2	X	772	125.0 – 163.0	7
	Consumers 33409	4	IX	751	120.0 – 150.0	6
Lake Erie						
	Consumers Amoco 13076	51	A	957	95.0 – 125.0	18
	Consumers Pan Am 13057	56	E	999	90.0 – 128.0	71
	Consolidated West CT-1	234	M	117	60.0 – 81.5	5
	Consolidated West CT-6	234	L	113	63.0 – 72.6	76

Appendix B. continued

County and Township	Drill Hole	Lot	Conc.	Core or Tray (T) #	Depth Logged (m)	Drill Hole Number (this study)
Lambton County						
Brooke Township						
	Leesa-Imperial 1-13-I	13	I	546	115.0 – 138.3	19
Dawn Township						
	Leesa-Dawn 19-XIII	19	XIII	383	96.9 – 108.8	46
	Leesa-Imperial 4-27-XIII	27	XIII	590	120.0 – 143.3	9
Euphemia Township						
	NYK Oil–Monroe No. 1	27	IV	6457 (T)	96.3 – 110.0	143
Enniskillen Township						
	Imperial 831	18	I	595	100.0 – 130.0	10
	Imperial 838	18	II	605	91.0 – 121.0	11
Moore Township						
	Argor 65-1	28	II	538	245.0 – 328.0	12
	Imperial 547	10	IX	532	170.0 – 192.2	13
	Imperial 661 Corunna 18	20	X	603	190.0 – 220.0	14
	OGS-82-1	18	Front	n/a	270.0 – 344.3	51
Sarnia Township						
	Imperial 700 Ref. 11	8	Range 2	601	180.0 – 240.0	20
	M.O.E. Deep Obs. # 1	12	Range 4	954	180.0 – 285.0	15
Middlesex County						
McGillivray Township						
	Imperial 809	5	XIX	220	50.0 – 140.0	21
Metcalfe Township						
	Earl-Bolton No. 1	6	II	2097 (T)	110.3 – 142.2	147
Mosa Township						
	Mitchell #3	7	V	358	113.0 – 123.0	22
	Walker 502	6	VI	895	102.1 – 114.6	23
	Allegany Prod. W. 112	6	VI	302	102.5 – 121.3	24
	Secord 601	6	VI	894	98.1 – 113.4	25
Oxford County						
North Oxford Township						
	Domtar Beachville 72-5	18	II	924	4.6 – 23.5	29
	Domtar Beachville 72-10			929	15.2 – 32.6	30
	Domtar Beachville 72-12			931	21.9 – 38.7	30.5
West Zorra Township						
	Canada Cement Lafarge 85-17	2	III	952	0.0 – 30.0	28

This page left blank intentionally

Appendix C

Summary of Depositional Lithofacies

Appendix C. Summary of depositional lithofacies.

APPALACHIAN BASIN LITHOFACIES

A1: Supratidal to Intertidal facies
A2: Marginal Marine facies
A3: Subtidal facies
A4: Biostromal facies (proximal and distal)
A5: Restricted Lagoonal facies

Facies A1: Supratidal to Intertidal facies

- tan, light grey to light brown
- laminated, thin to medium bedded mudstone
- very finely crystalline to micritic
- dark bituminous laminations
- occasional angular mudstone intraclasts
- common very fine to fine peloids; fenestral
- occasional thin organic-rich layers
- sparsely sandy with well-rounded, fine quartz grains
- sparsely fossiliferous

Facies A2: Marginal Marine facies

- tan, grey to light brown
- calcareous orthoquartzitic sandstone to fossiliferous sandy limestone in a micritic mudstone matrix
- occasional mudstone intraclasts
- stromatoporoid-coral floatstone, boundstone to rudstone interbeds. Common tabular and dendritic stromatoporoid fragments, thamnoporid corals and stromatoporoid-encrusted colonial rugose coral branches (*Synaptophyllum*?). *Amphipora* and *Aulopora* fragments also occur
- massive, planar to cross-stratified sandstone beds
- quartz grains are fine to very fine, subangular to well rounded
- commonly peloidal

Facies A3: Shallow Subtidal facies

- tan, brown to cream coloured
- sparse to moderately fossiliferous; medium bedded
- wackestone-packstone-grainstone textures common
- commonly peloidal with fenestral micritic mudstone beds
- floatstone pulses in a mudstone to wackestone matrix with dendritic to tabular stromatoporoids, thamnoporid corals, small gastropods, colonial rugose coral fragments and uncommon small tabulate coral fragments
- occasional thin rudstone pulses
- uncommon bluish-grey-light brown mottled mudstone beds
- uncommon thin carbonaceous seams

Facies A4: Biostromal facies

[Proximal (A4P) and Distal (A4D)]

- tan to light brown
- finely crystalline, medium bedded and moderately to very fossiliferous

- boundstone textures dominant in proximal biostrome facies, with common irregular, laminar, tabular and massive stromatoporoids interbedded with finely crystalline subtidal facies
- distal biostrome facies textures are primarily thick, well sorted rudstones and floatstones. These pulses are made up predominantly of lower energy back-reef and reef flank fossils such as thamnoporid corals, *Amphipora* and colonial rugose corals

Facies A5: Restricted Lagoonal facies

- brown to dark brown, thinly bedded micritic lime mudstones with thin black carbonaceous seams
- sparsely to non-fossiliferous

MICHIGAN BASIN LITHOFACIES

M1: Upper Sabkha Mud Flat facies
M2: Lower Sabkha Mud Flat facies
M3: Supratidal to Shallow Intertidal facies
M4: Subtidal facies

Facies M1: Upper Sabkha Mud Flat facies

- tan, grey to white or bluish
- massive to nodular anhydrite with occasional thin brown dolomudstone beds
- common bladed to tabular gypsum? laths bounding dolomudstone beds pseudomorphed by anhydrite

Facies M2: Lower Sabkha Mud Flat facies

- tan, grey to brown
- thin bedded to massive, micritic to very finely crystalline dolomudstone with thin anhydrite (or anhydritic) interbeds
- anhydrite commonly brown-tan-whitish colour with a "clotted" texture
- thin (<1 cm wide), horizontal to subhorizontal satin spar-filled gypsum veins commonly found in dolomitic mudstone matrix.

Facies M3: Supratidal to Shallow Intertidal facies

- tan to light brown or light grey
- typically thinly bedded, laminated to algal-laminated with dark bituminous laminations
- microcrystalline to very finely crystalline mudstone
- sparsely to non-fossiliferous
- may be limestone or dolostone
- occasional thin intraformational breccias
- celestite / calcite-filled vugs uncommon
- common small (1 by 5 mm) anhydrite laths (often leached molds) "floating" in mudstone matrix
- may be sparsely sandy
- fenestral

Facies M4: Subtidal Facies

- tan, light grey, light brown to brown
- very fine to fine crystalline, medium bedded to massive
- mudstones and wackestone textures dominant with occasional peloidal packstone pulses
- commonly dolomitic
- sparsely fossiliferous; may have wispy argillaceous seams

Appendix D

Drill Core Lithologs

Notes:

1. Drill hole number for this study is shown in upper right corner of each litholog.
2. Carbonate classification shown represents entire interval of unit.
3. Degree of dolomitization indicated under "Diagenesis" column. If only 1 dolomitization value is shown for a unit, then it represents the entire unit interval; otherwise values represent the degree of dolomitization at the depth shown.

LEGEND FOR LITHOLOGS

Formation	Depth (m)	Lithology	Crystal, Grain or Fragment Size	Unit #	Classification	Framework %	Sorting	Diagenesis	Facies	Sample Location
1		2	3	4	5	6	7	8	9	10

COLUMN 1

POROSITY TYPES:

X	Intercrystalline, intergranular, interfragmental
ϕ	Interoolitic, interpelletoid
V	Vuggy (voids >0.06mm)
P	Pinpoint (voids <0.06mm)
∿	Moldic
O	Organic - bridged, intrafossil
F	Fracture
⊡	Fenestral

COLUMN 2

ROCK TYPE:

☐	Sandstone
▦	Limestone
▤	Dolostone
▨	Anhydrite (massive to clotted)
⁘	Anhydrite (massive to nodular)

ACCESSORIES:

- ⁖ , ⁖ Sandy, sandstone stringers
- •• , •••• Silty, siltstone stringers
- — , —— Argillaceous, shale laminae
- ■ , ▬ Carbonaceous flakes, seams
- / / , ⫽⫽ Anhydritic, anhydrite stringers
- \ \ , ⫽⫽ Gypsiferous, gypsum stringers
- ⊥ Dolomitic
- ⊥⊥ Dolostone stringers
- ⊥ Calcareous
- ⊥⊥ Limestone stringers
- P Pyrite
- ✱ Mineral crystals
- △ Chert

SKELETAL AND NON-SKELETAL GRAINS:

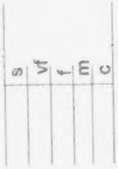
- ⊥⊥ Stromatoporoids
- ⌒ Domal stromatoporoids
- ■ Amphipora
- ⌒ Corals
- ⌒ Algal laminae
- ⊙ Crinoids
- ◎ Gastropods
- ○ Ostracods
- ◡ Bivalves
- ◡ Brachiopods
- ○ Echinoids
- ☆ Charophyte oogonia
- ⋂ Bryozoans
- F Fossils <20%
- ⌒ Bioclastic
- ø Pellets, pelloids
- ○ Ooids
- Y Intraclasts

PHYSICAL, BIOGENIC AND DIAGENIC FEATURES:

- ═ Planar lamination
- ⫽ Low-angle cross-lamination
- ⌒ , ∼ , ∼ Ripple cross-, small scale cross-, wave ripple cross-laminations
- ∩∪ Convolute/distorted lamination
- — — Intraformation breccia
- ∼ Disrupted lamination
- ∨ Desiccation cracks
- ∼∼∼ Erosional contact
- S, SS, SSS Bioturbation: weak, moderate thorough
- ⊤ Vertical burrows
- ∼ Hardground
- □ Fenestral texture
- ≠ Zebra mottled

COLUMN 3

CRYSTAL, GRAIN OR FRAGMENT SIZE:



SILT	0.004-0.0625 mm
SAND	
very fine	0.0625-0.125 mm
fine	0.125-0.250 mm
medium	0.250-0.500 mm
coarse	0.500-1.000 mm

COLUMN 5

LIMESTONE/DOLOSTONE CLASSIFICATION

(after Dunham 1962; Emby and Klovan 1971):

(DOMINANT, minor)

M,m	Mudstone	R,r	Rudstone
W,w	Wackestone	BO,bo	Boundstone
P,p	Packstone	BA,ba	Bafflestone
G,g	Grainstone	BI,bi	Bindstone
FL,fl	Floatstone	FR,fr	Framestone

COLUMN 6

FRAMEWORK:

0	0 TO 5%	5	50%
1	10%	6	60%
2	20%	7	70%
3	30%	8	80%
4	40%	9	90%
		C	100%

COLUMN 7

SORTING:

W	Well
M	Medium
P	Poor

COLUMN 8

DIAGENESIS:

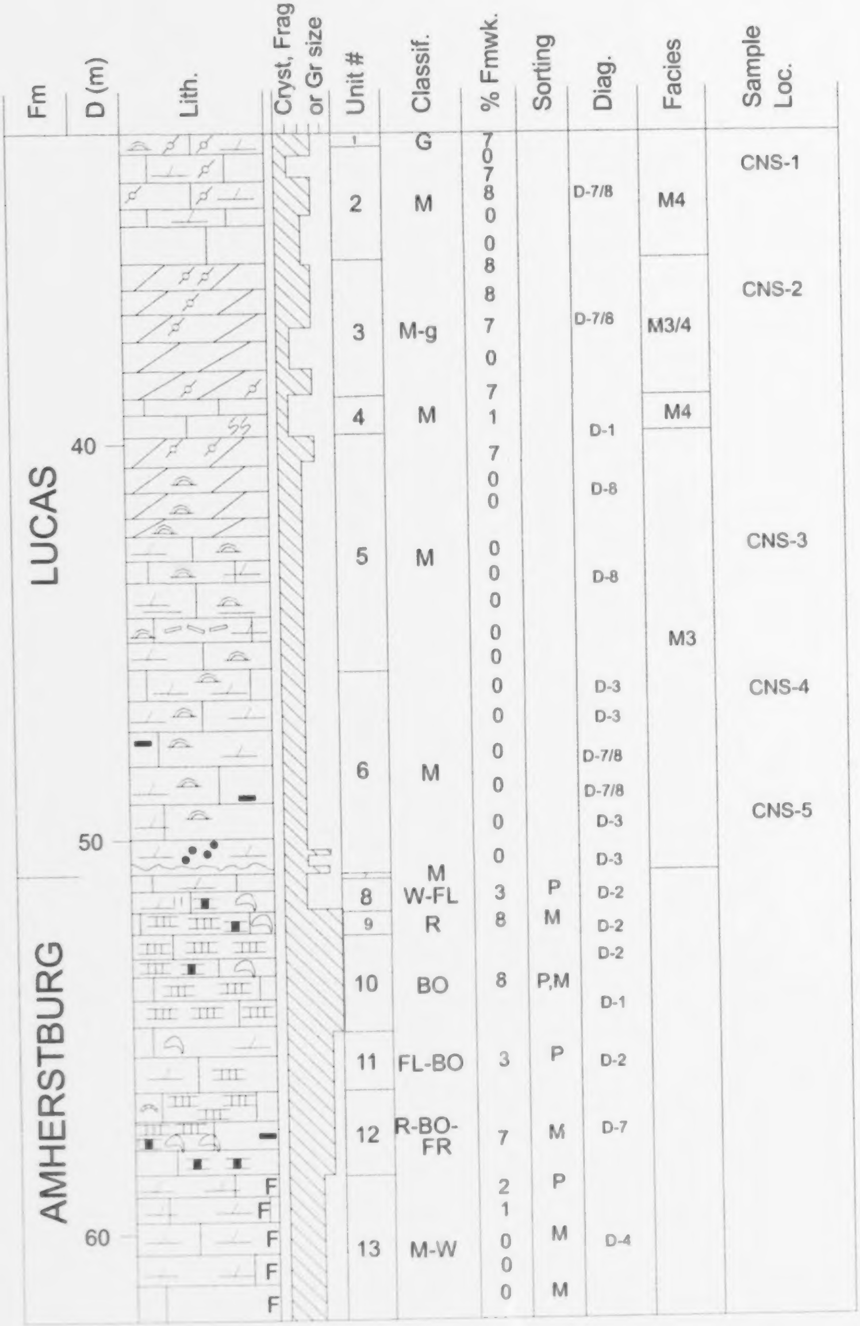
Type	D	Dolomitization	Degree	1	10%	6	60%
	R	Recrystallization		2	20%	7	70%
				3	30%	8	80%
				4	40%	9	90%
				5	50%	C	100%

COLUMN 9

FACIES:

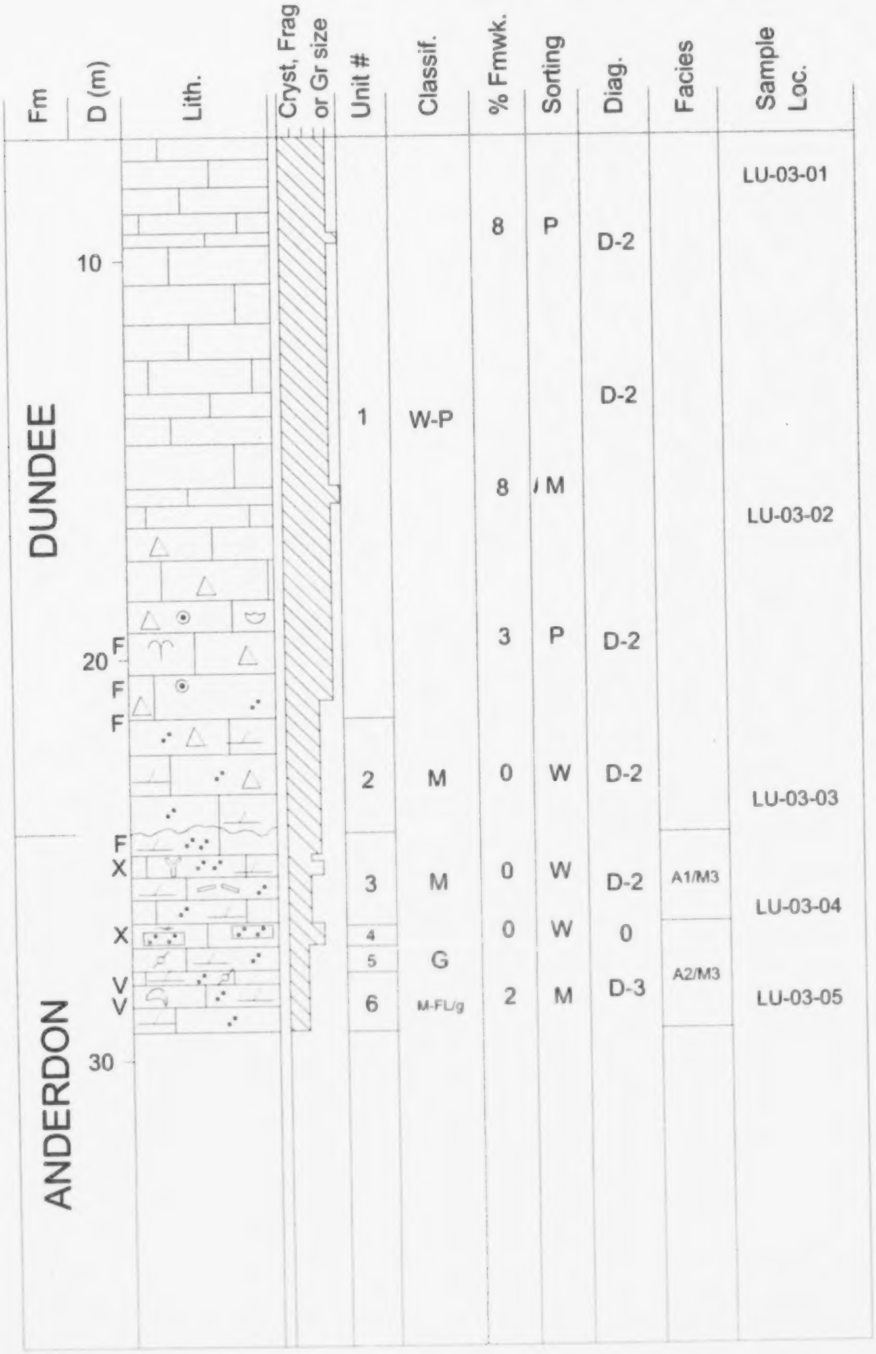
APPALACHIAN BASIN FACIES	A1	Supratidal/Intertidal	MICHIGAN BASIN FACIES	M1	Massive anhydrite
	A2	Marginal marine		M2	Anhydritic dolomite
	A3	Shallow subtidal		M3	Supratidal/Shallow intertidal
	A4	Biostromal (Proximal and Distal)		M4	Subtidal
	A5	Restricted Lagoonal			

Cansalt DDH 87-3
Fighting Island
Essex Co., Sandwich West Township (#1)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
AMHERSTBURG
40
50
60
1
G
2
M
3
M-g
4
M
5
M
6
M
M
8
W-FL
9
R
10
BO
11
FL-BO
12
R-BO-FR
13
M-W
70
78
00
88
70
71
70
0
0
0
0
0
0
0
0
0
0
0
0
0
3
8
8
3
7
21
0
0
0
P
M
P,M
P
M
P
M
M
D-7/8
D-7/8
D-1
D-8
D-8
D-3
D-3
D-7/8
D-7/8
D-3
D-3
D-2
D-2
D-2
D-1
D-2
D-7
D-4
M4
M3/4
M4
M3
CNS-1
CNS-2
CNS-3
CNS-4
CNS-5
F
F
F
F
F

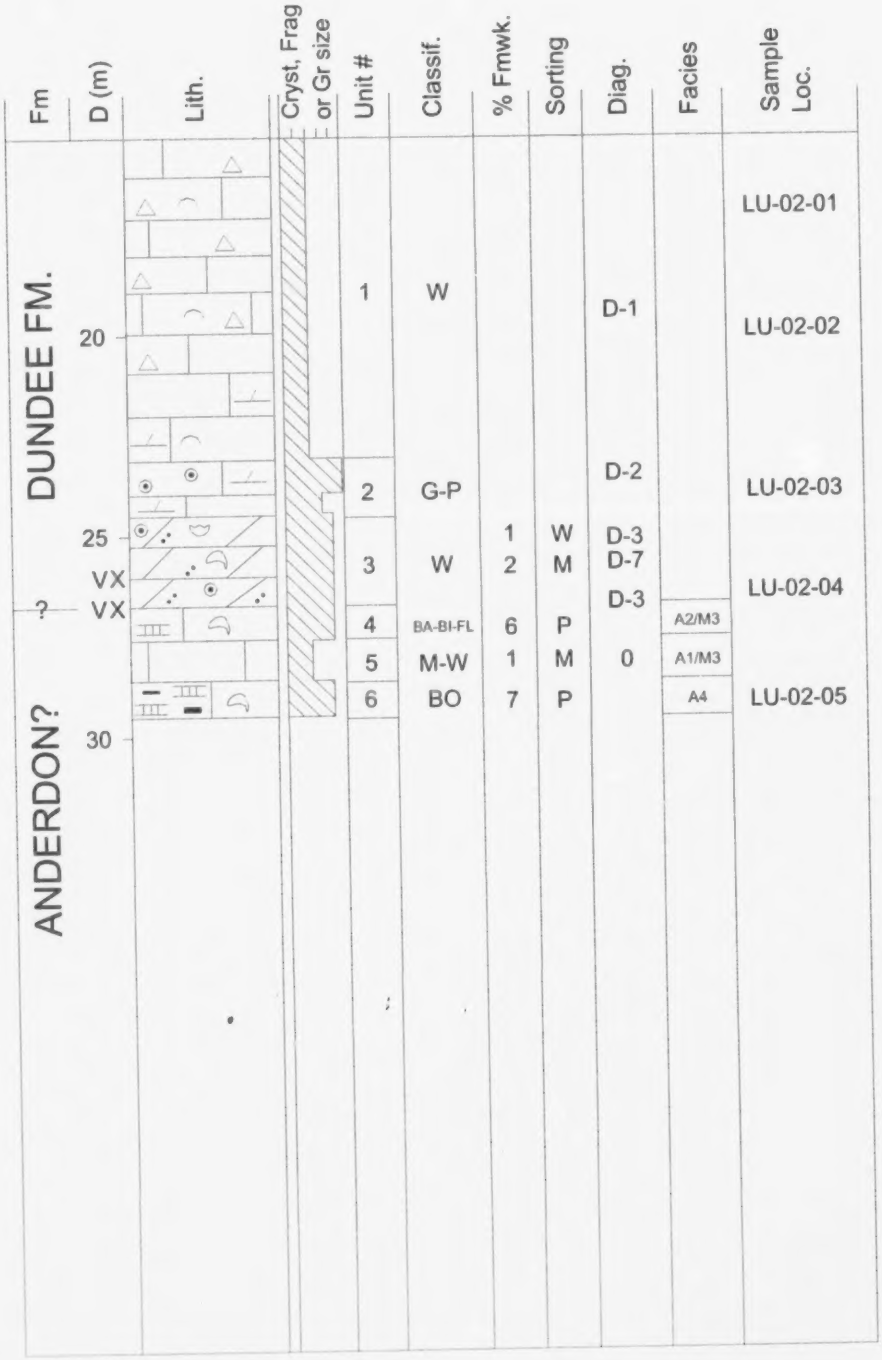
Lucas No. 3
Essex Co., Anderdon Twp.

(#2)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
ANDERDON
10
20
30
F
F
F
F
X
X
V
V
1
W-P
2
M
3
M
4
5
G
6
M-FL/g
8
P
8
M
3
P
0
W
0
W
0
W
2
M
D-2
D-2
D-2
D-2
D-2
0
D-3
A1/M3
A2/M3
LU-03-01
LU-03-02
LU-03-03
LU-03-04
LU-03-05

Lucas No. 2
Essex Co., Colchester S. Twp.

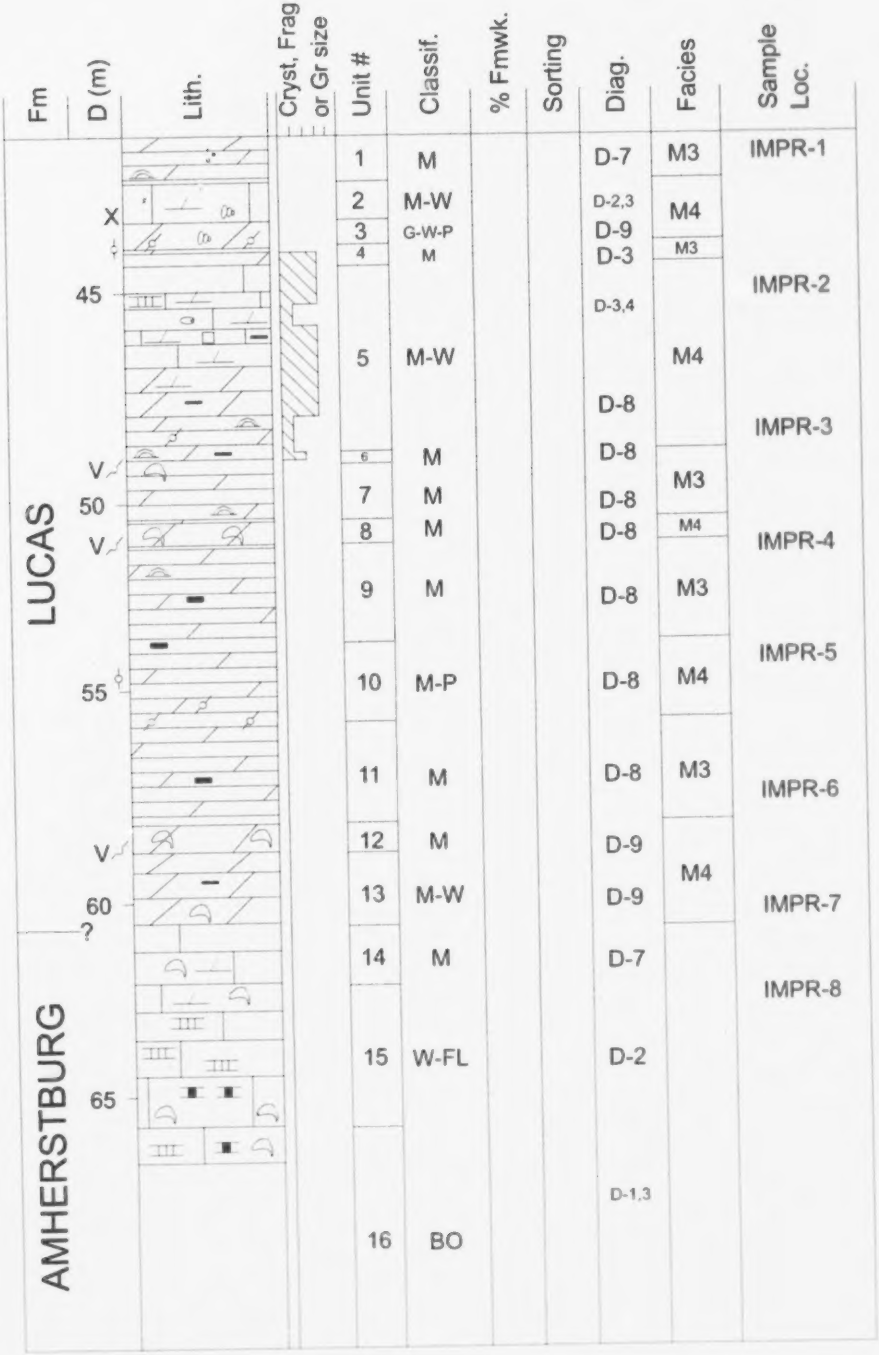
(#3)



Fm	D (m)	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE FM.	20	1	W			D-1		LU-02-01 LU-02-02
		2	G-P			D-2		LU-02-03
	25 VX	3	W	1 2	W M	D-3 D-7 D-3		LU-02-04
?	VX	4	BA-BI-FL	6	P		A2/M3	
ANDERDON?		5	M-W	1	M	0	A1/M3	
	30	6	BO	7	P		A4	LU-02-05

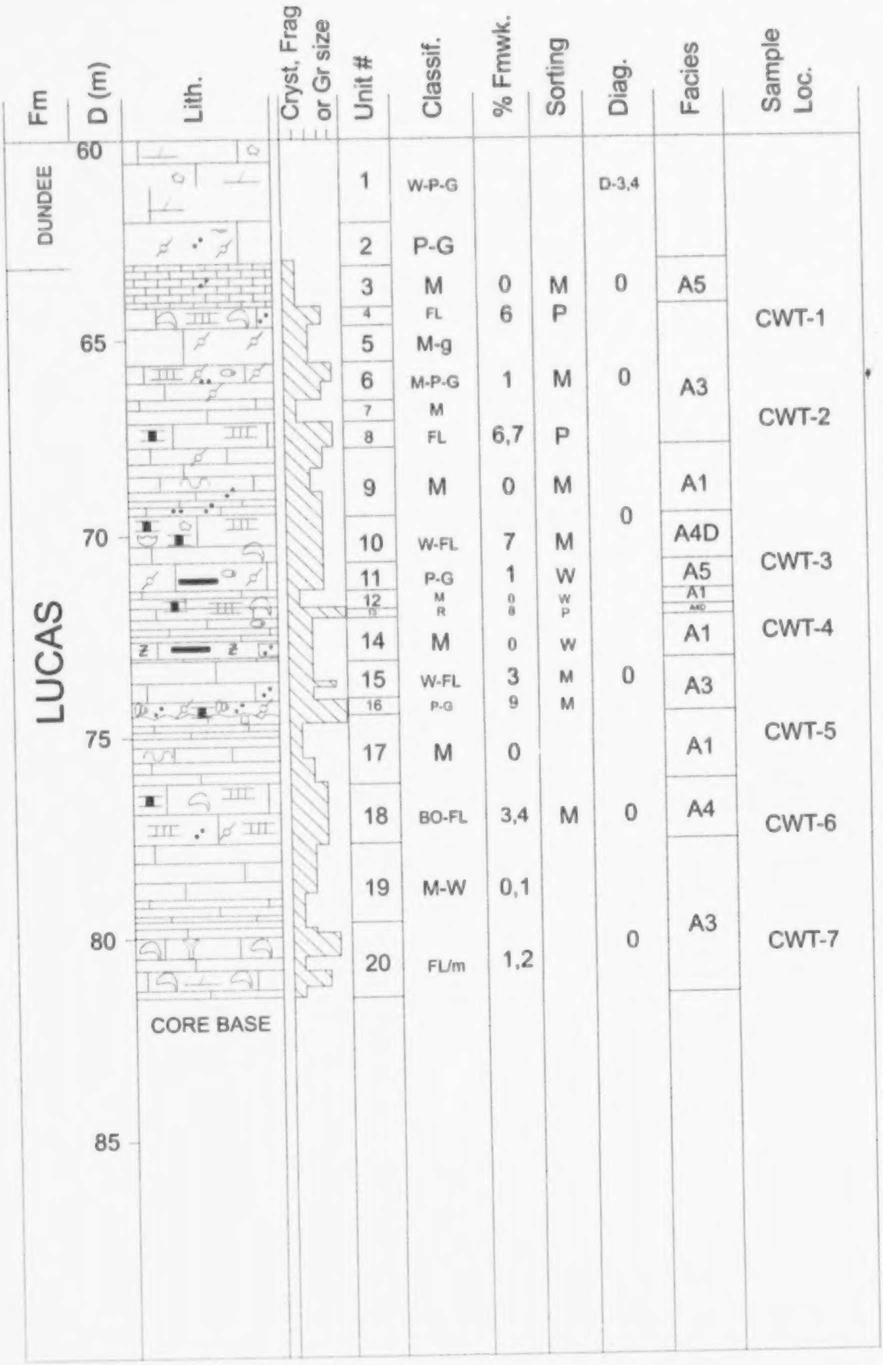
Lith.
Cryst, Frag or Gr size

Imperial Et. Al. 813
Essex Co., Gosfield S. Twp. (#4)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
AMHERSTBURG
45
50
55
60
65
X
V
V
V
?
1
M
D-7
M3
IMPR-1
2
M-W
D-2,3
M4
3
G-W-P
D-9
4
M
D-3
M3
IMPR-2
D-3,4
5
M-W
M4
D-8
IMPR-3
6
M
D-8
M3
7
M
D-8
8
M
D-8
M4
IMPR-4
9
M
D-8
M3
IMPR-5
10
M-P
D-8
M4
11
M
D-8
M3
IMPR-6
12
M
D-9
M4
13
M-W
D-9
IMPR-7
14
M
D-7
IMPR-8
15
W-FL
D-2
D-1,3
16
BO

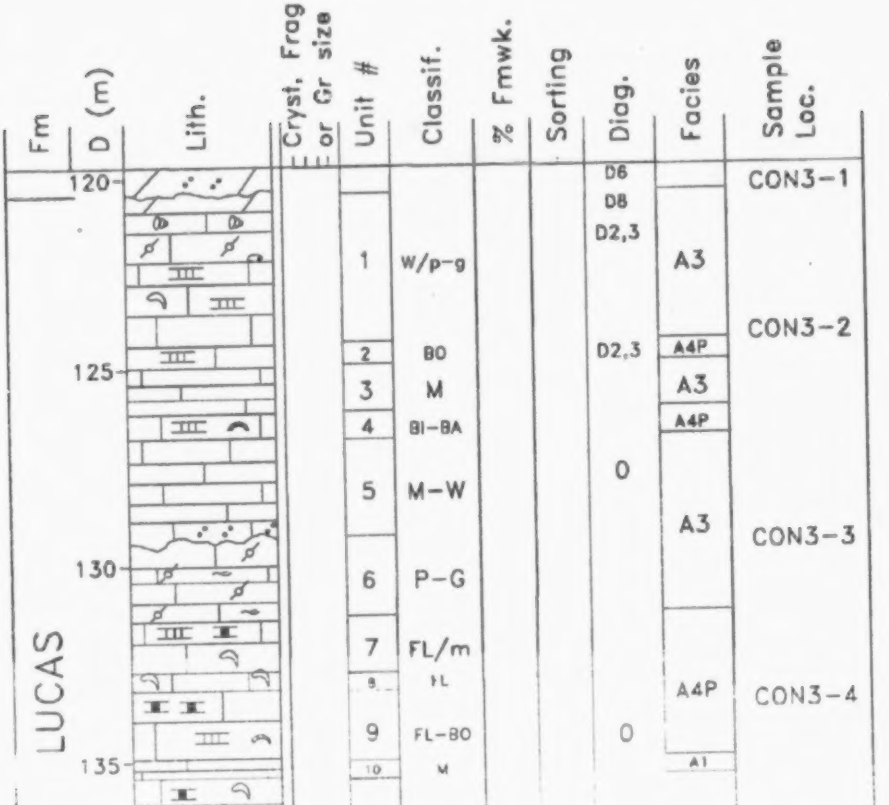
Consolidated West CT-1
Lake Erie

(#5)

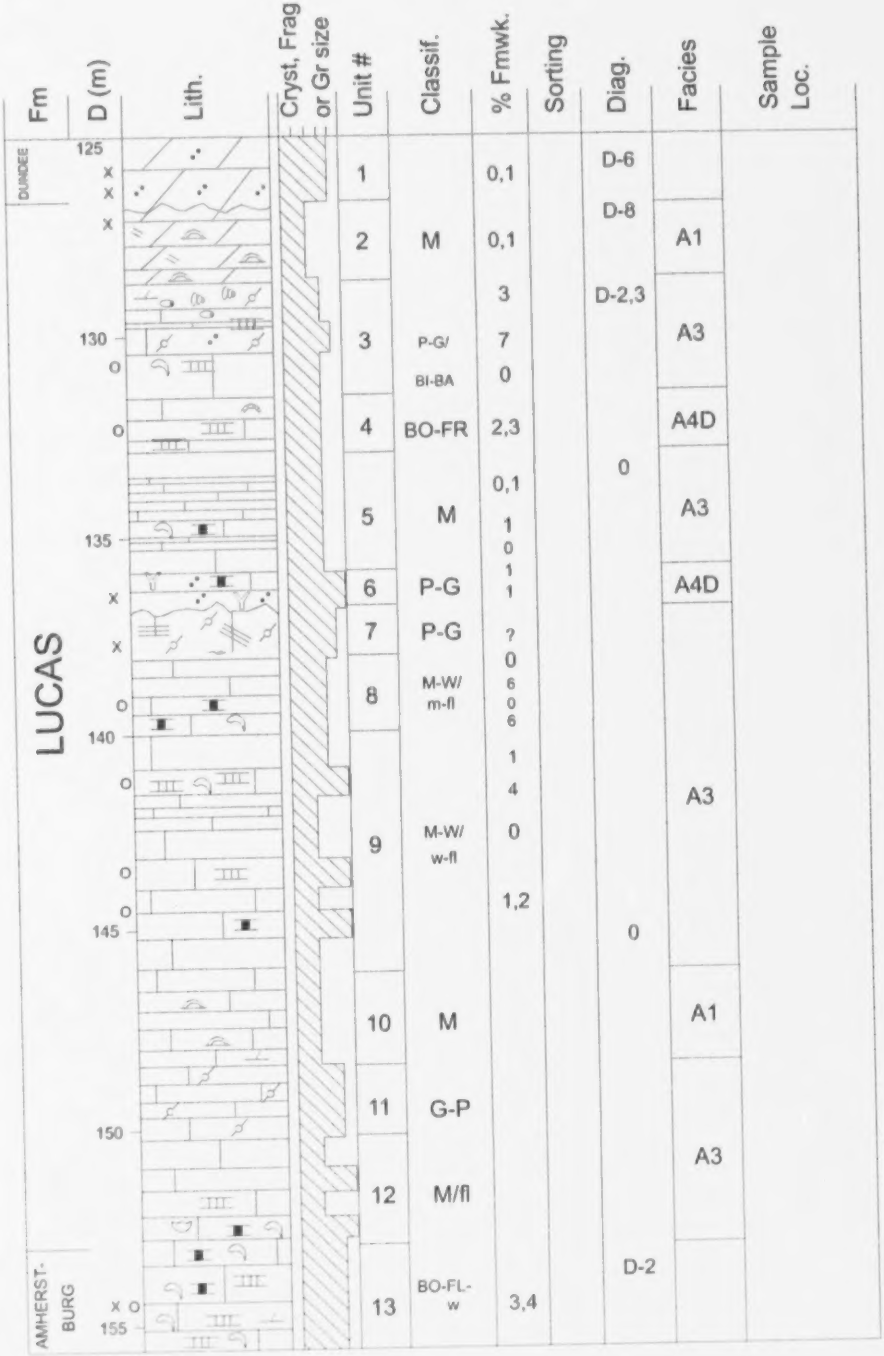

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
60
65
70
75
80
85
CORE BASE

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE	1	W-P-G			D-3,4		
	2	P-G					
LUCAS	3	M	0	M	0	A5	
	4	FL	6	P		A3	CWT-1
	5	M-g					
	6	M-P-G	1	M	0		
	7	M					CWT-2
	8	FL	6,7	P			
	9	M	0	M	0	A1	
	10	W-FL	7	M		A4D	
	11	P-G	1	W		A5	CWT-3
	12	M	0	W		A1	
	13	R	8	P		A4D	
	14	M	0	W		A1	CWT-4
	15	W-FL	3	M	0	A3	
	16	P-G	9	M			
	17	M	0			A1	CWT-5
	18	BO-FL	3,4	M	0	A4	CWT-6
	19	M-W	0,1			A3	
	20	FL/m	1,2		0		CWT-7

Consumers 33409
Kent Co., Tilbury E. Twp. (#6)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
AMHERSTBURG
120
125
130
135
140
145
150
1 W/p-g
2 BO
3 M
4 BI-BA
5 M-W
6 P-G
7 FL/m
8 FL
9 FL-BO
10 M
11 BI-BA-W/m-w
12 M
13 FL/w-m
14 BO
15 BO
D6
D8
D2,3
D2,3
0
0
0
0
D2
0
A3
A4P
A3
A4P
A3
A4P
A1
A4P
A1
A4P
CON3-1
CON3-2
CON3-3
CON3-4
CON3-5

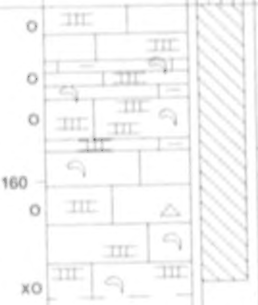
Consumers 33408A
Kent Co., Tilbury E. Twp (#7)



Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
AMHERST-BURG
125
130
135
140
145
150
155
x
o
1
0,1
D-6
2
M
0,1
D-8
A1
3
P-G/ Bl-BA
3
7
0
D-2,3
A3
4
BO-FR
2,3
A4D
5
M
0,1
1
0
A3
0
6
P-G
1
1
A4D
7
P-G
?
8
M-W/ m-fl
0
6
0
6
9
M-W/ w-fl
1
4
0
1,2
A3
0
10
M
A1
11
G-P
12
M/fl
A3
13
BO-FL-w
3,4
D-2

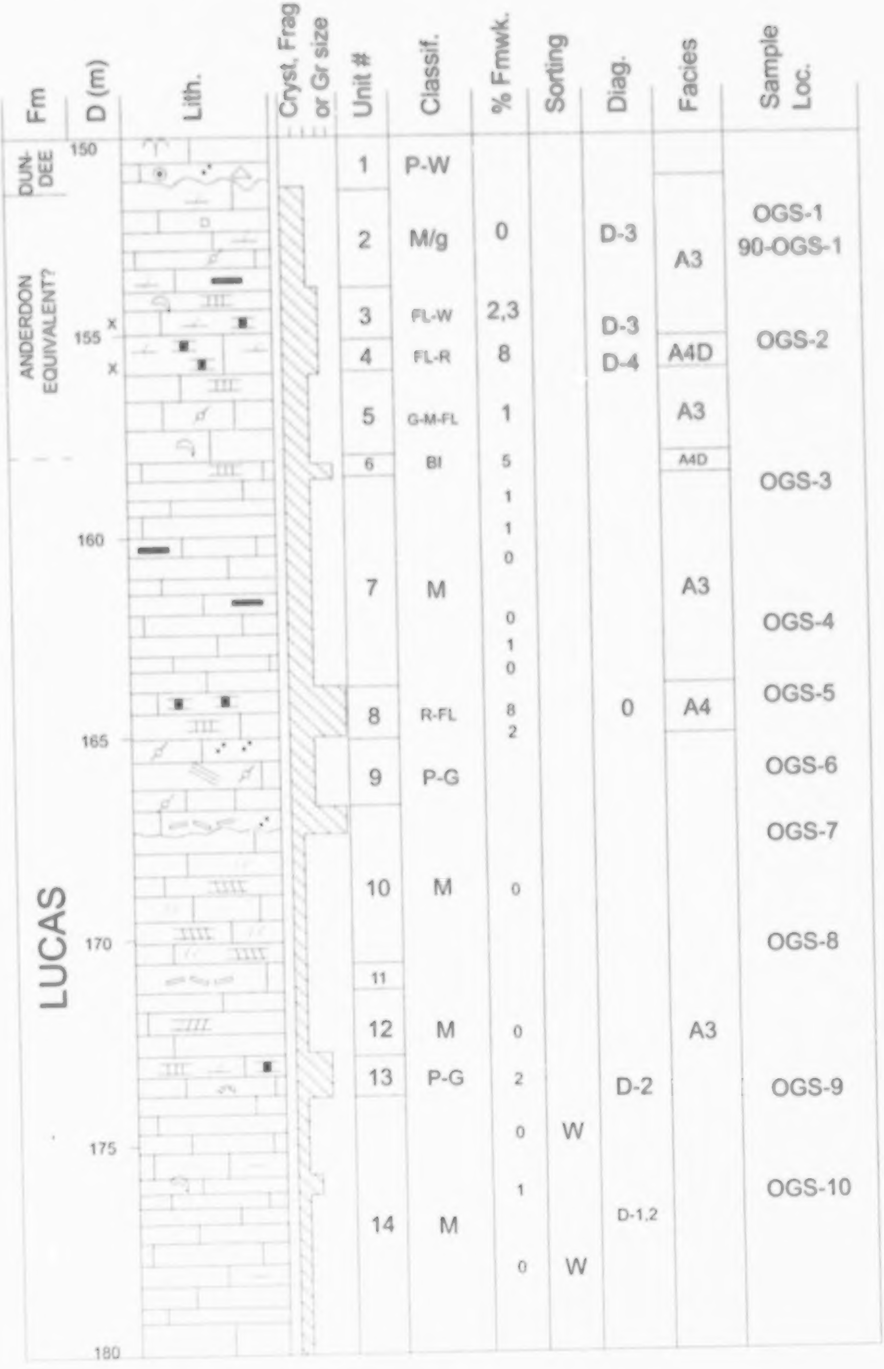
Consumers 33408A
Kent Co., Tilbury E. Twp.
Continued

(#7)



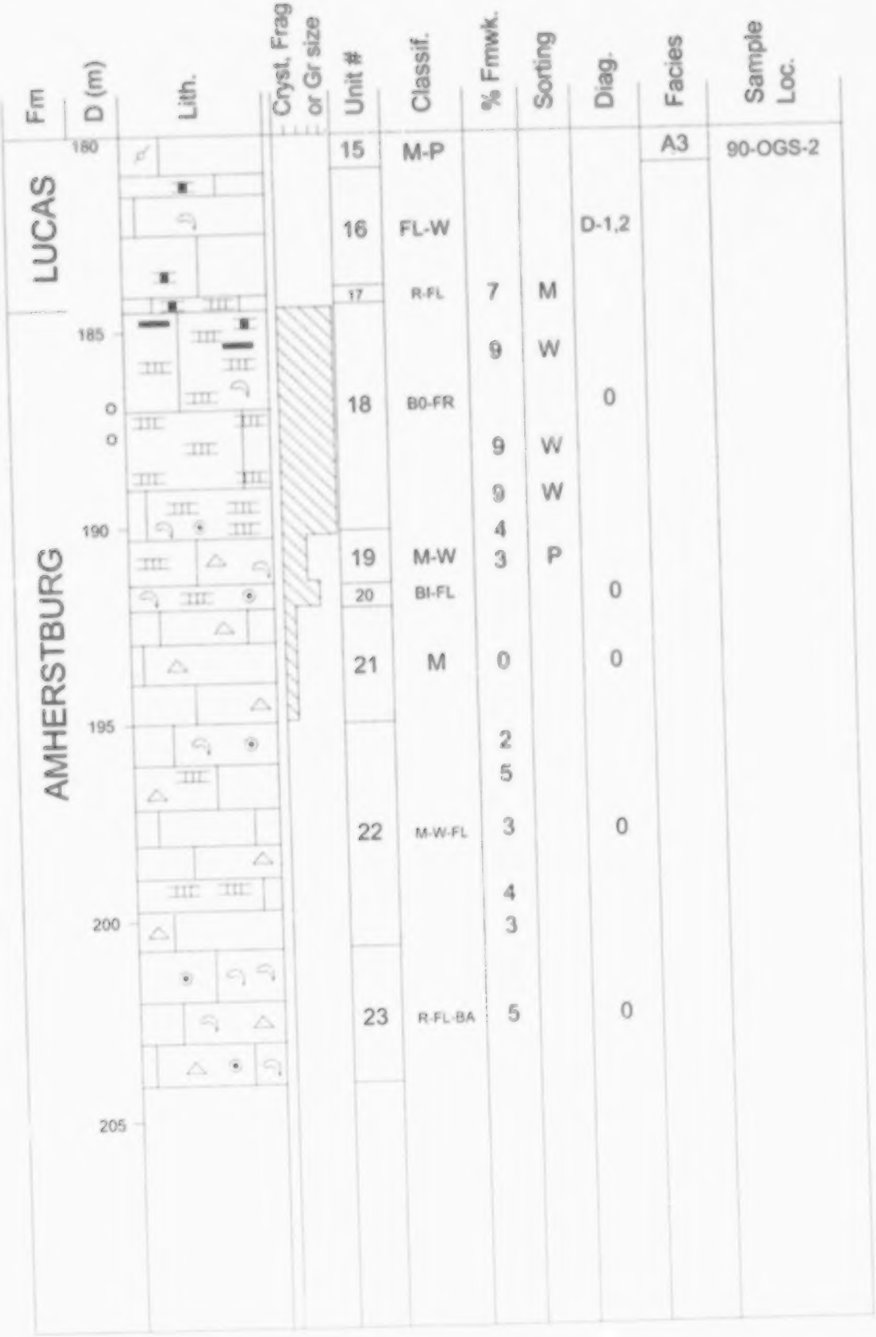
Fm	D (m)	Lith.	Cryst. Frag or Gr size	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
AMHERSTBURG				14	BO/bo-fl	8		0		
				15	FL-BA-m-w	3	P	0		
				16	BO	9		D-1,2		

OGS-82-2
Kent Co., Harwich Twp. (#8)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUN-DEE
ANDERDON EQUIVALENT?
LUCAS
150
155
160
165
170
175
180
x
x
1 P-W
2 M/g 0 D-3 A3 OGS-1 90-OGS-1
3 FL-W 2,3 D-3
4 FL-R 8 D-4 A4D OGS-2
5 G-M-FL 1 A3
6 Bl 5 A4D OGS-3
1
1
0
7 M A3
0 OGS-4
1
0
8 R-FL 8 2 0 A4 OGS-5
9 P-G OGS-6
OGS-7
10 M 0
OGS-8
11
12 M 0 A3
13 P-G 2 D-2 OGS-9
0 W
1 OGS-10
14 M D-1,2
0 W

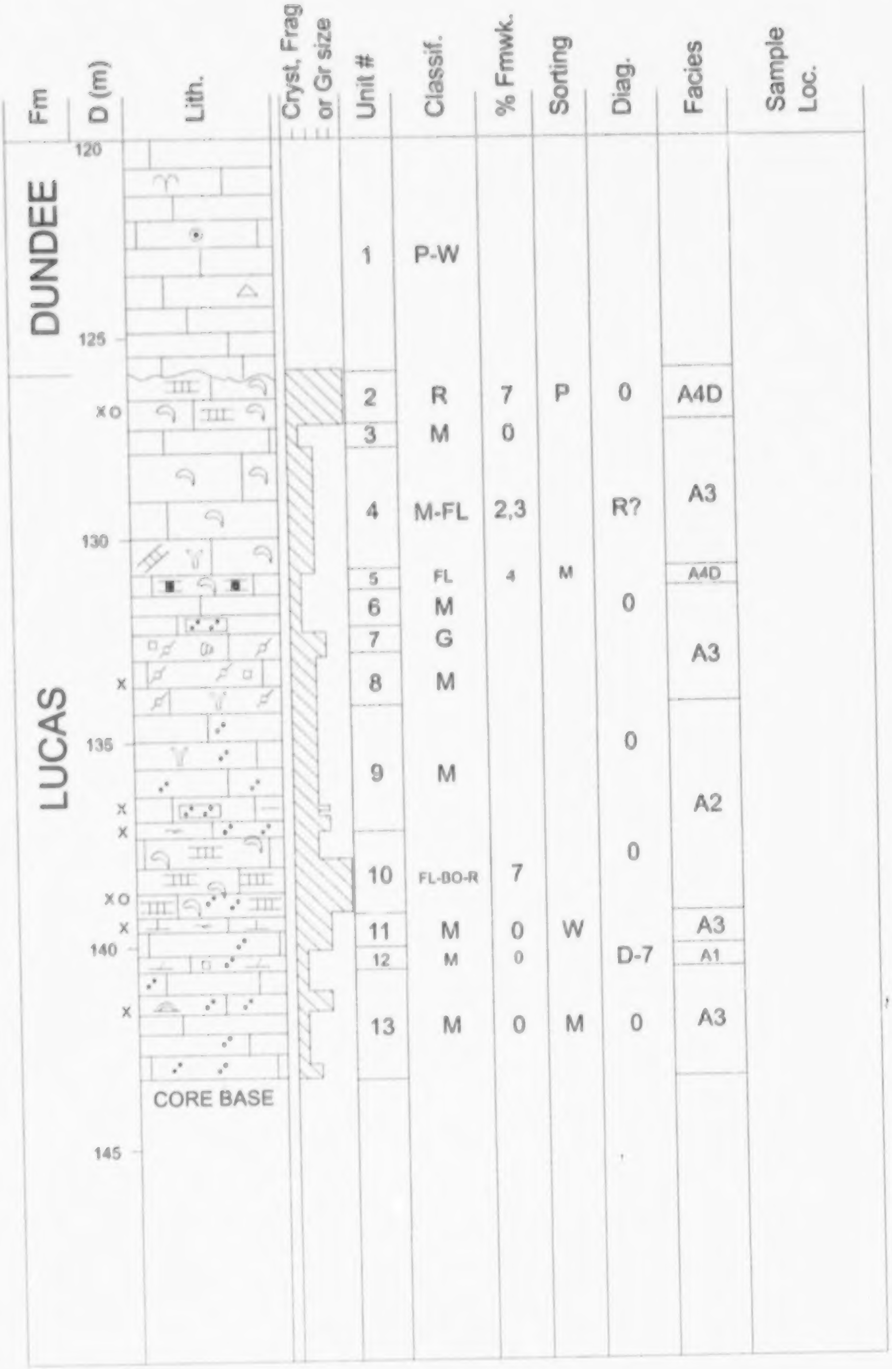
OGS-82-2
Kent Co., Harwich Twp.
Continued

(#8)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
AMHERSTBURG
180
185
190
195
200
205
15
M-P
A3
90-OGS-2
16
FL-W
D-1,2
17
R-FL
7
M
9
W
18
B0-FR
0
9
W
9
W
4
19
M-W
3
P
20
BI-FL
0
21
M
0
0
2
5
22
M-W-FL
3
0
4
3
23
R-FL-BA
5
0

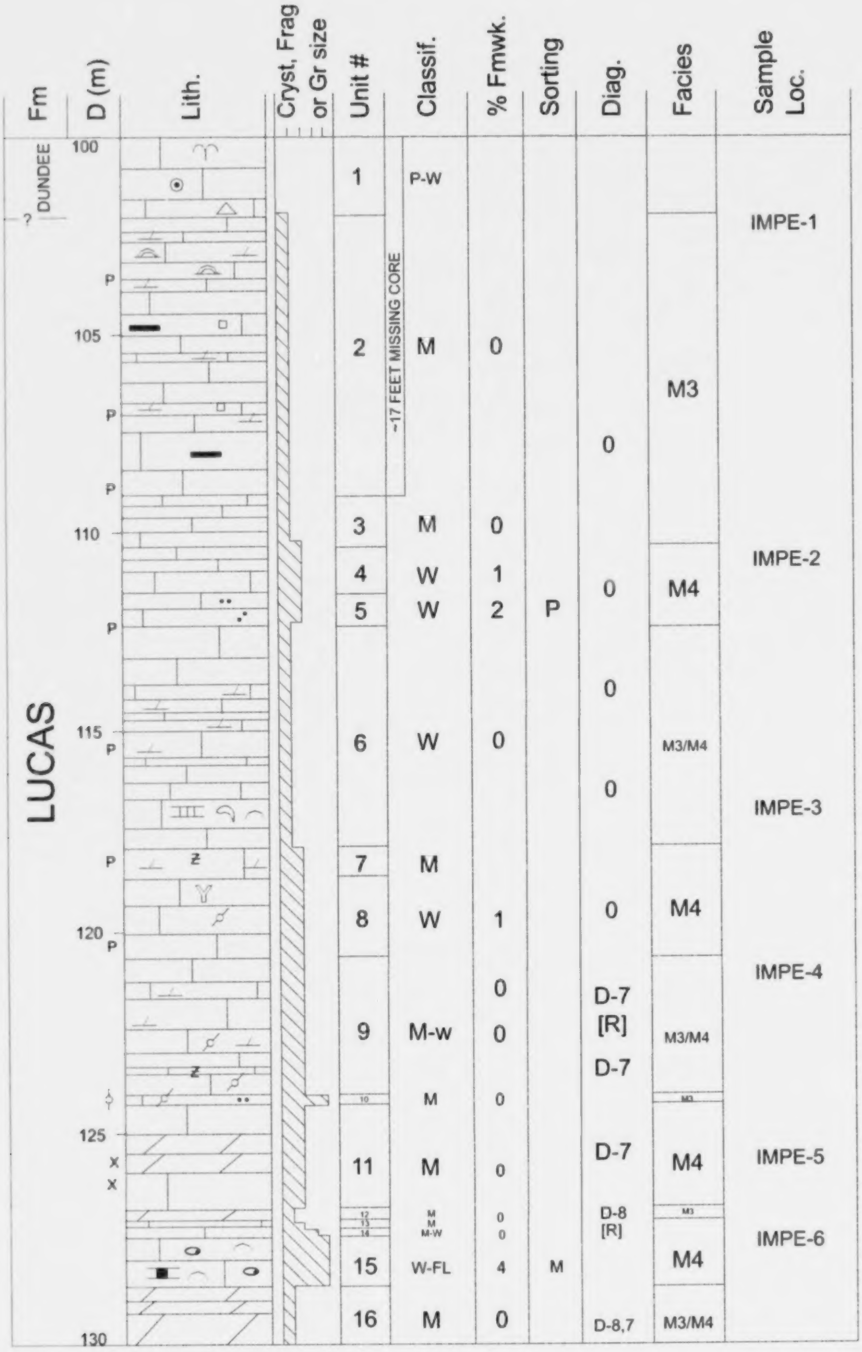
Leesa-Imperial 27-XIII
Lambton Co., Dawn Twp.

(#9)

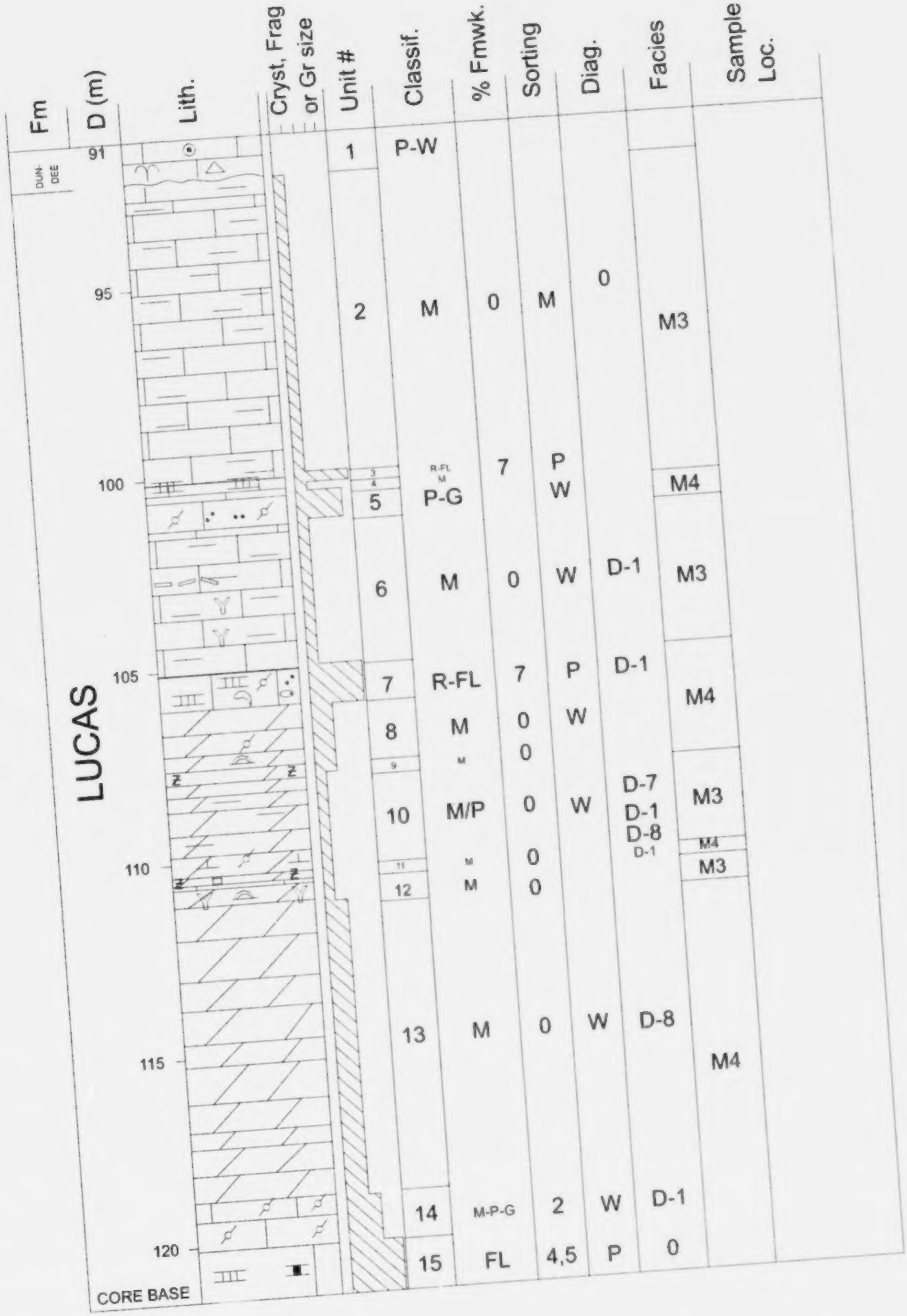

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
120
125
130
135
140
145
x o
x
x
x
x o
x
x
CORE BASE

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies
DUNDEE	1	P-W				
LUCAS	2	R	7	P	0	A4D
	3	M	0			A3
	4	M-FL	2,3		R?	
	5	FL	4	M		A4D
	6	M			0	A3
	7	G				
	8	M				
	9	M			0	A2
	10	FL-BO-R	7		0	
	11	M	0	W		A3
	12	M	0		D-7	A1
	13	M	0	M	0	A3

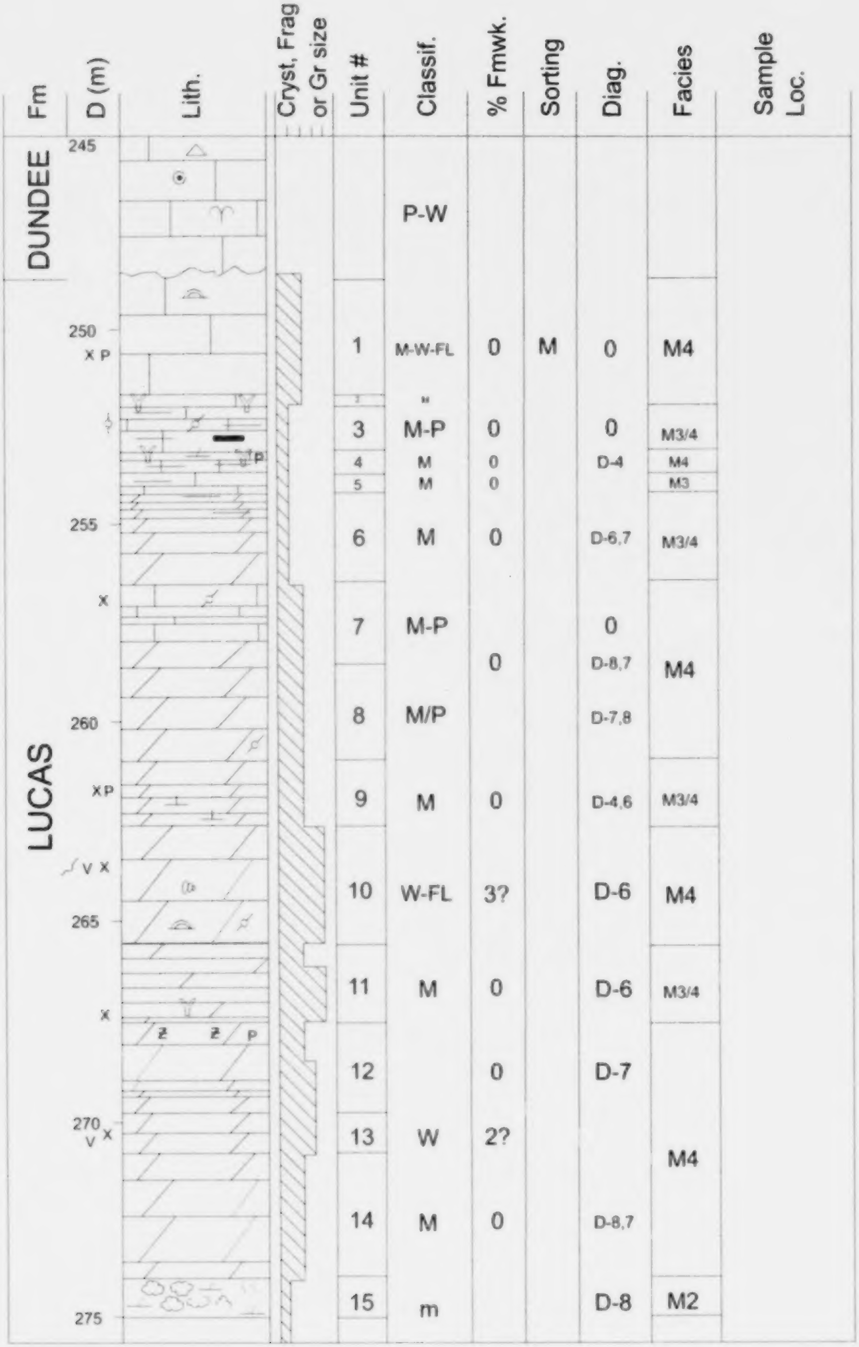
Imperial 831
Lambton Co., Enniskillen Twp. (#10)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
?
LUCAS
100
105
110
115
120
125
130
P
P
P
P
P
P
P
X
X
~17 FEET MISSING CORE
1
P-W
2
M
0
3
M
0
4
W
1
5
W
2
P
6
W
0
7
M
8
W
1
9
M-w
0
0
10
M
0
11
M
0
12
M
0
13
M
0
14
M-W
15
W-FL
4
M
16
M
0
0
0
0
0
0
D-7
[R]
D-7
D-7
D-8
[R]
D-8,7
M3
M4
M3/M4
M4
M3/M4
M3
M4
M3
M4
M3/M4
IMPE-1
IMPE-2
IMPE-3
IMPE-4
IMPE-5
IMPE-6

Imperial No. 838 (#11)
Lambton Co., Enniskillen Twp.


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUN-DEE
LUCAS
91
95
100
105
110
115
120
CORE BASE
1 P-W
2 M 0 M 0 M3
3
4
R-FL
M
7
P
W
M4
5 P-G
6 M 0 W D-1 M3
7 R-FL 7 P D-1 M4
8 M 0 W
9 M 0
10 M/P 0 W D-7 D-1 D-8 D-1 M3 M4 M3
11 M 0
12 M 0
13 M 0 W D-8 M4
14 M-P-G 2 W D-1
15 FL 4,5 P 0

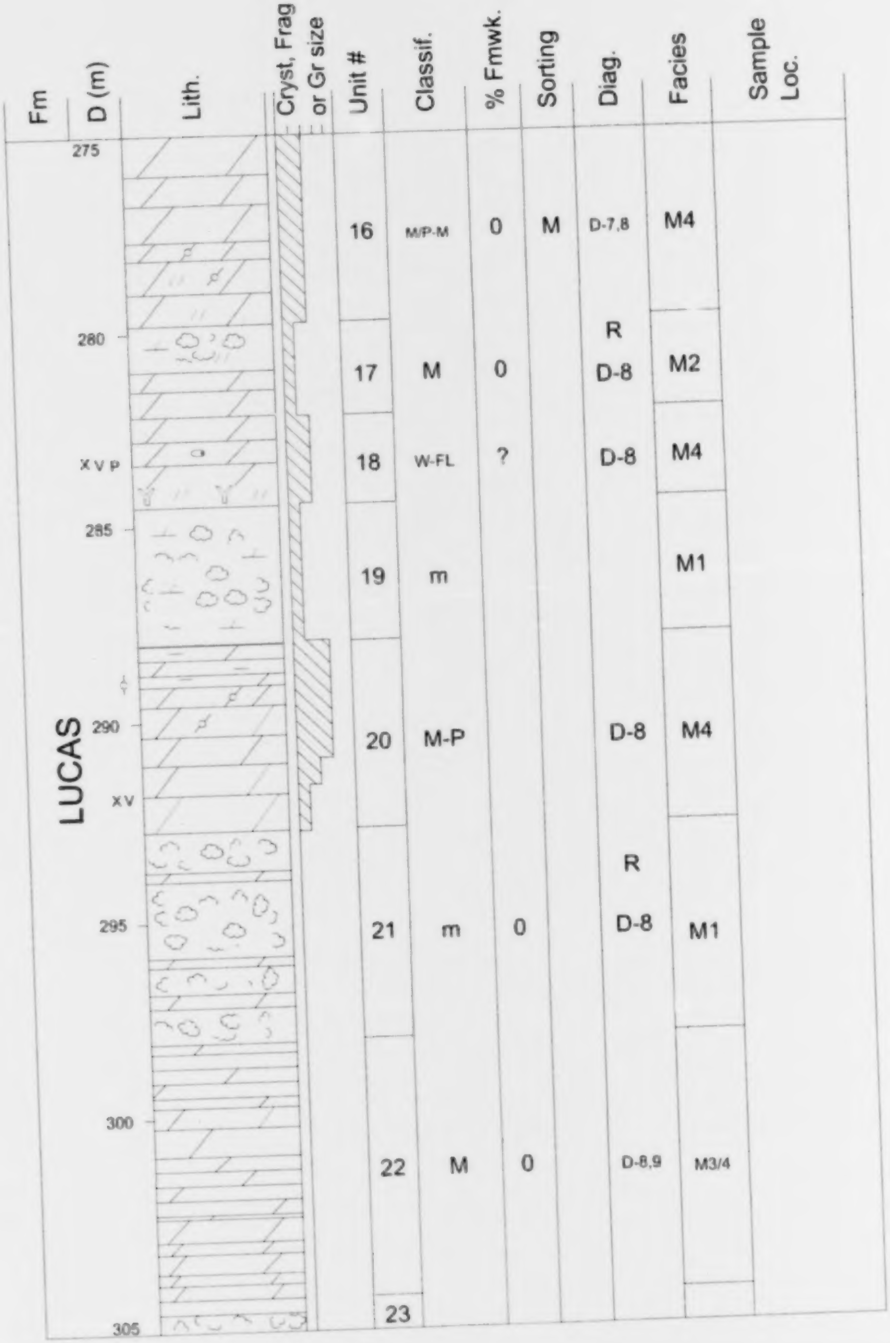
Argor 65-1
Lambton Co., Moore Twp. (#12)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
DUNDEE
LUCAS
245
250
X P
255
X
260
X P
V X
265
X
270
V X
275
P
P

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE		P-W					
LUCAS	1	M-W-FL	0	M	0	M4	
	2	"					
	3	M-P	0		0	M3/4	
	4	M	0		D-4	M4	
	5	M	0			M3	
	6	M	0		D-6,7	M3/4	
	7	M-P	0		0 D-8,7	M4	
	8	M/P			D-7,8		
	9	M	0		D-4,6	M3/4	
	10	W-FL	3?		D-6	M4	
	11	M	0		D-6	M3/4	
	12		0		D-7	M4	
	13	W	2?				
	14	M	0		D-8,7		
	15	m			D-8	M2	

Argor 65-1
Lambton Co., Moore Twp.
Continued

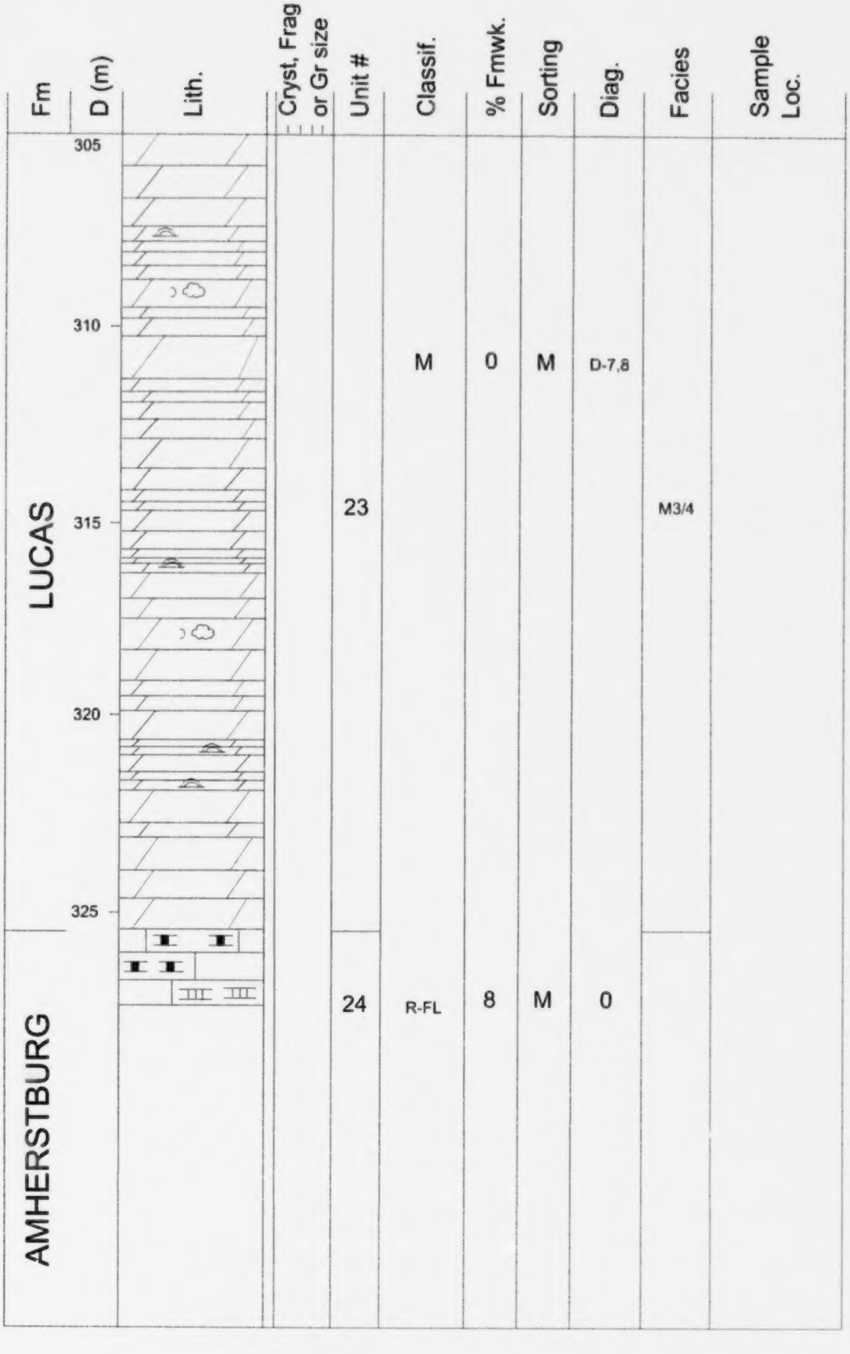
(#12)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
275
280
X V P
285
290
X V
295
300
305
LUCAS

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
LUCAS	16	M/P-M	0	M	D-7,8	M4	
	17	M	0		R D-8	M2	
	18	W-FL	?		D-8	M4	
	19	m				M1	
	20	M-P			D-8	M4	
	21	m	0		R D-8	M1	
	22	M	0		D-8,9	M3/4	
	23						

Argor 65-1
Lambton Co., Moore Twp.
Continued

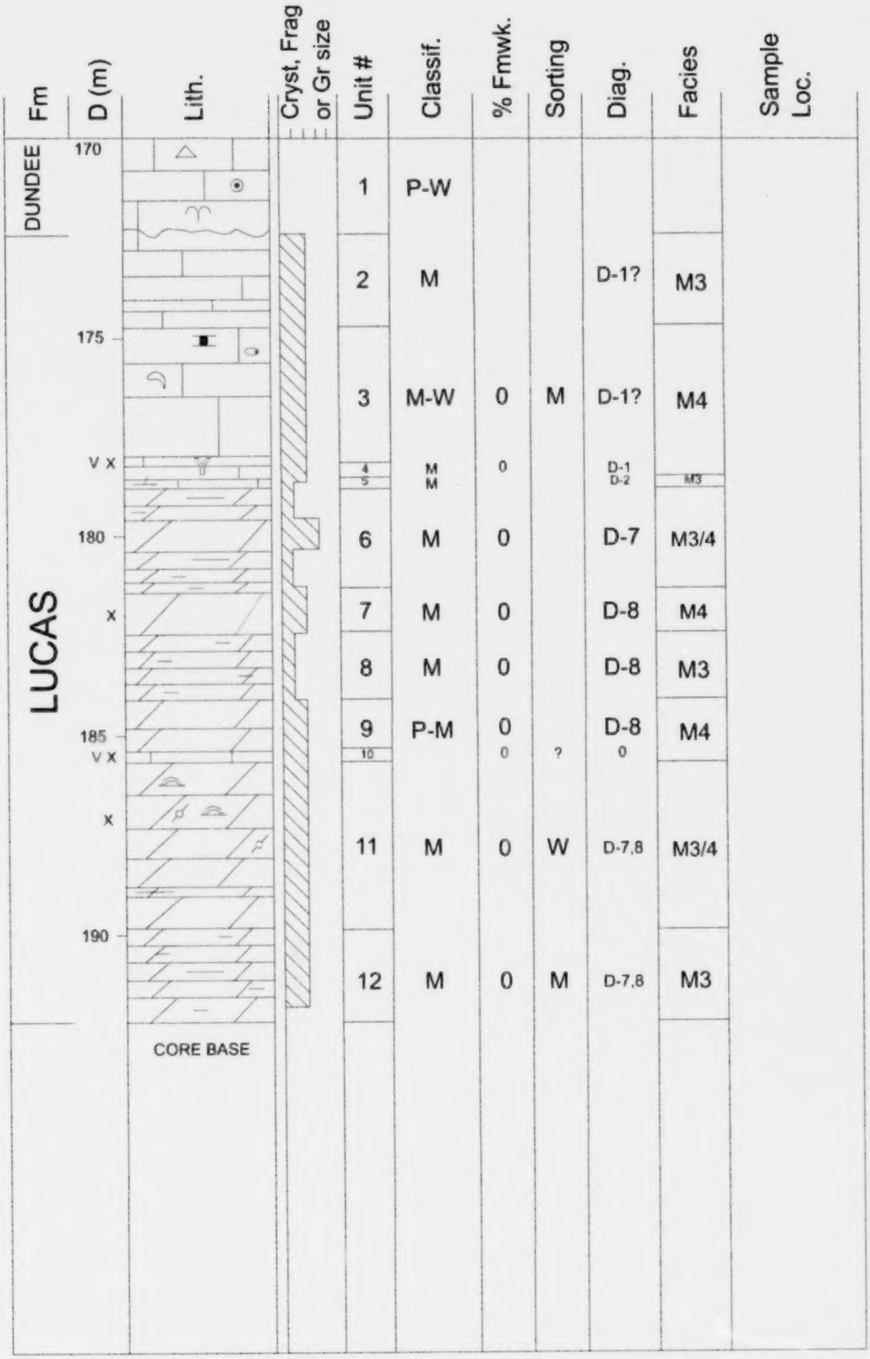
(#12)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
305
310
315
320
325

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
LUCAS	23	M	0	M	D-7,8	M3/4	
AMHERSTBURG	24	R-FL	8	M	0		

Imperial #547
Lambton Co., Moore Twp.

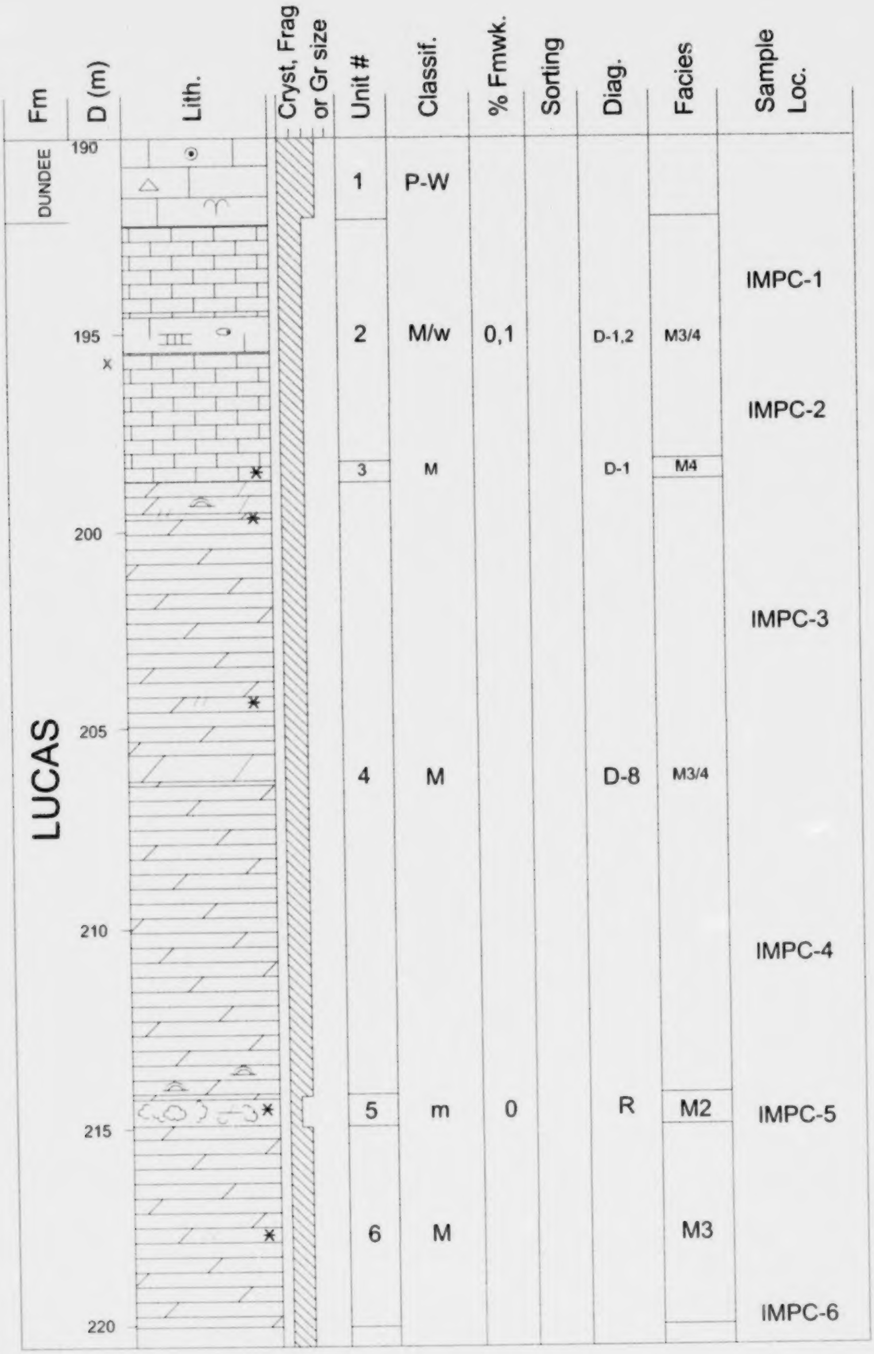
(#13)



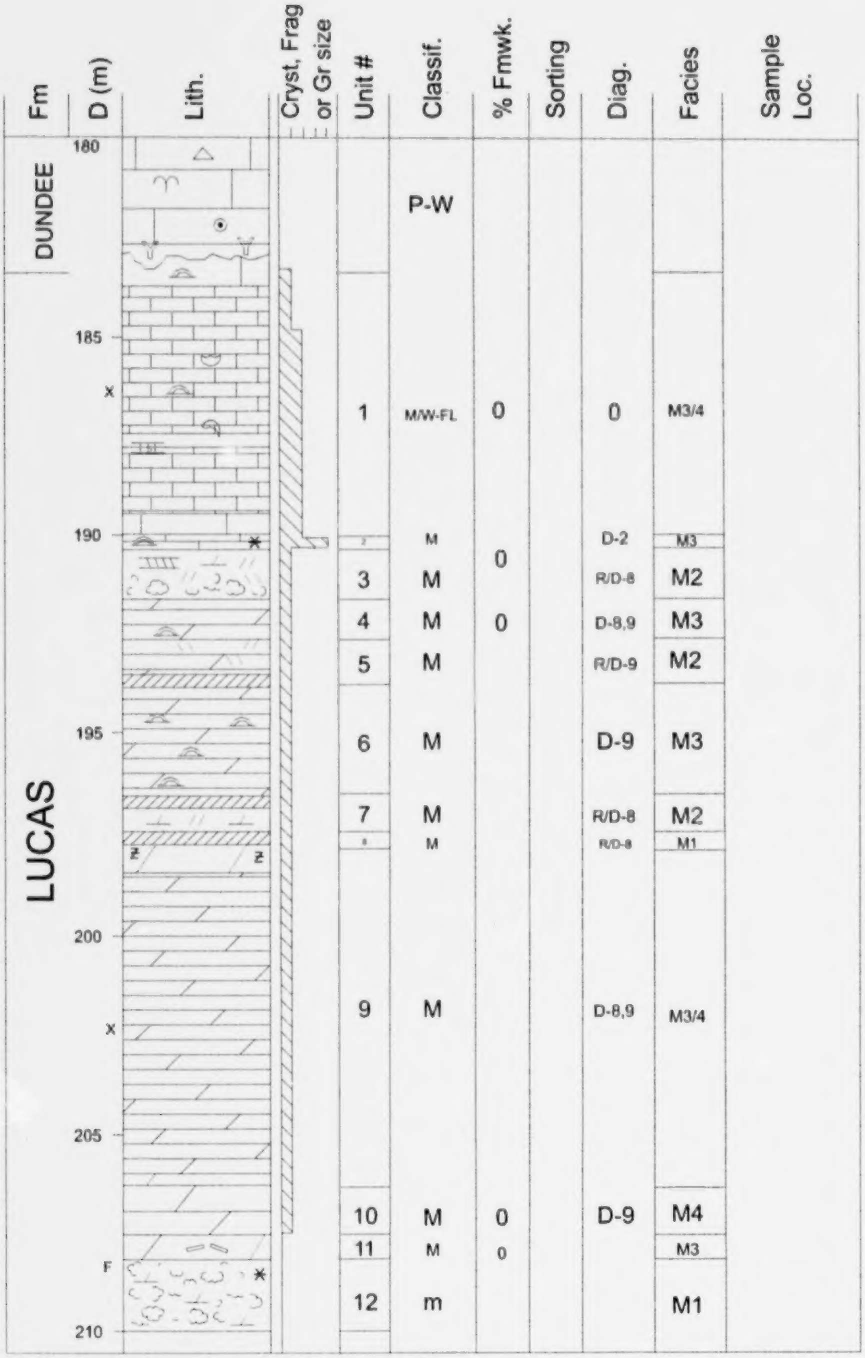
Fm
D (m)
Lith.
Cryst, Frag or Gr size
Sample Loc.
DUNDEE
LUCAS
170
175
180
185
190
V X
X
V X
X
CORE BASE

Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies
1	P-W				
2	M			D-1?	M3
3	M-W	0	M	D-1?	M4
4	M	0		D-1	
5	M			D-2	M3
6	M	0		D-7	M3/4
7	M	0		D-8	M4
8	M	0		D-8	M3
9	P-M	0		D-8	M4
10		0	?	0	
11	M	0	W	D-7,8	M3/4
12	M	0	M	D-7,8	M3

Imperial #661 Corunna 18
Lambton Co., Moore Twp. (#14)

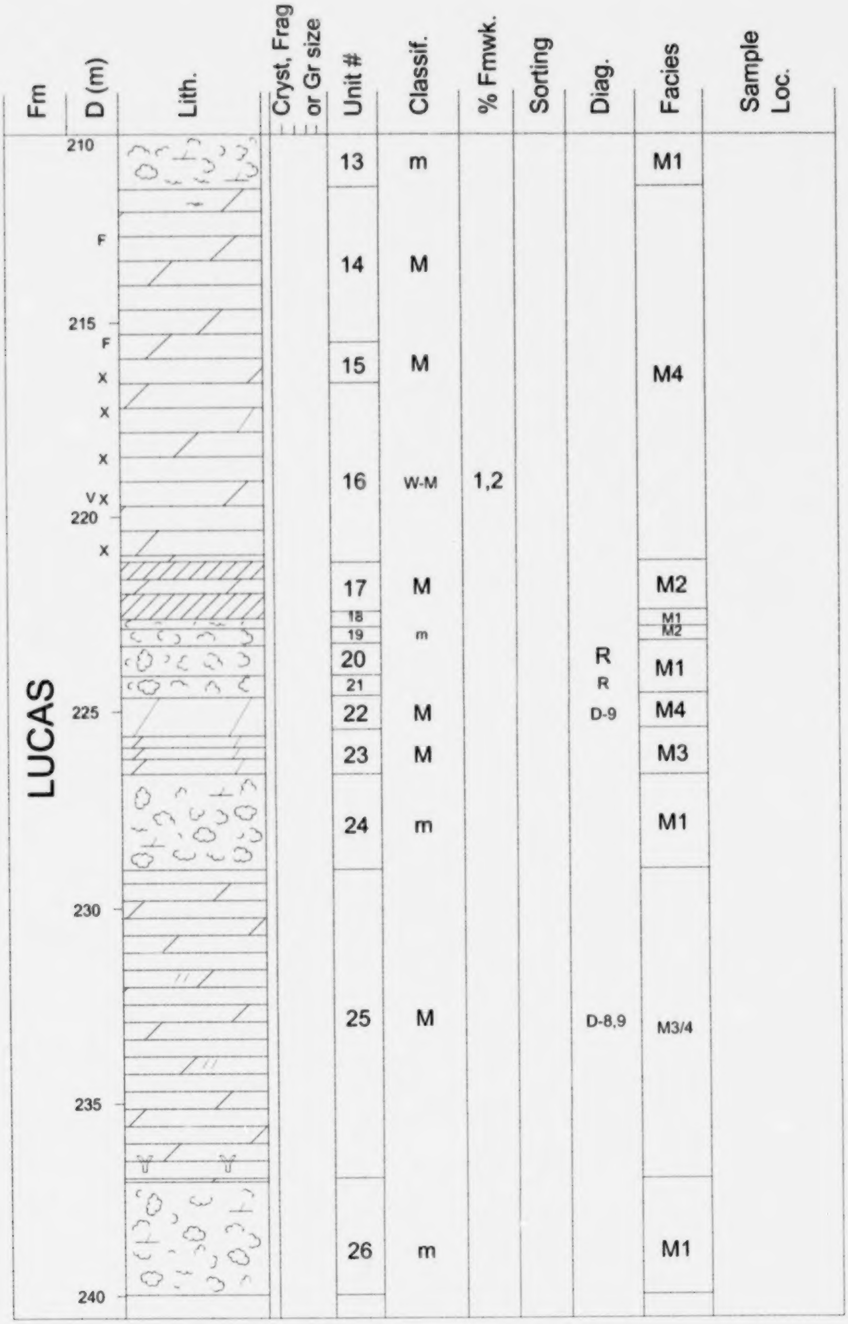

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
190
195
200
205
210
215
220
X
1
P-W
2
M/w
0,1
D-1,2
M3/4
IMPC-1
IMPC-2
3
M
D-1
M4
IMPC-3
4
M
D-8
M3/4
IMPC-4
5
m
0
R
M2
IMPC-5
6
M
M3
IMPC-6

MOE Deep OBS #1
Lambton Co., Sarnia Twp. (#15)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
180
185
190
195
200
205
210
x
x
F
DUNDEE
LUCAS
P-W
1
M/W-FL
0
0
M3/4
M
D-2
M3
3
M
0
R/D-8
M2
4
M
0
D-8,9
M3
5
M
R/D-9
M2
6
M
D-9
M3
7
M
R/D-8
M2
M
R/D-8
M1
9
M
D-8,9
M3/4
10
M
0
D-9
M4
11
M
0
M3
12
m
M1

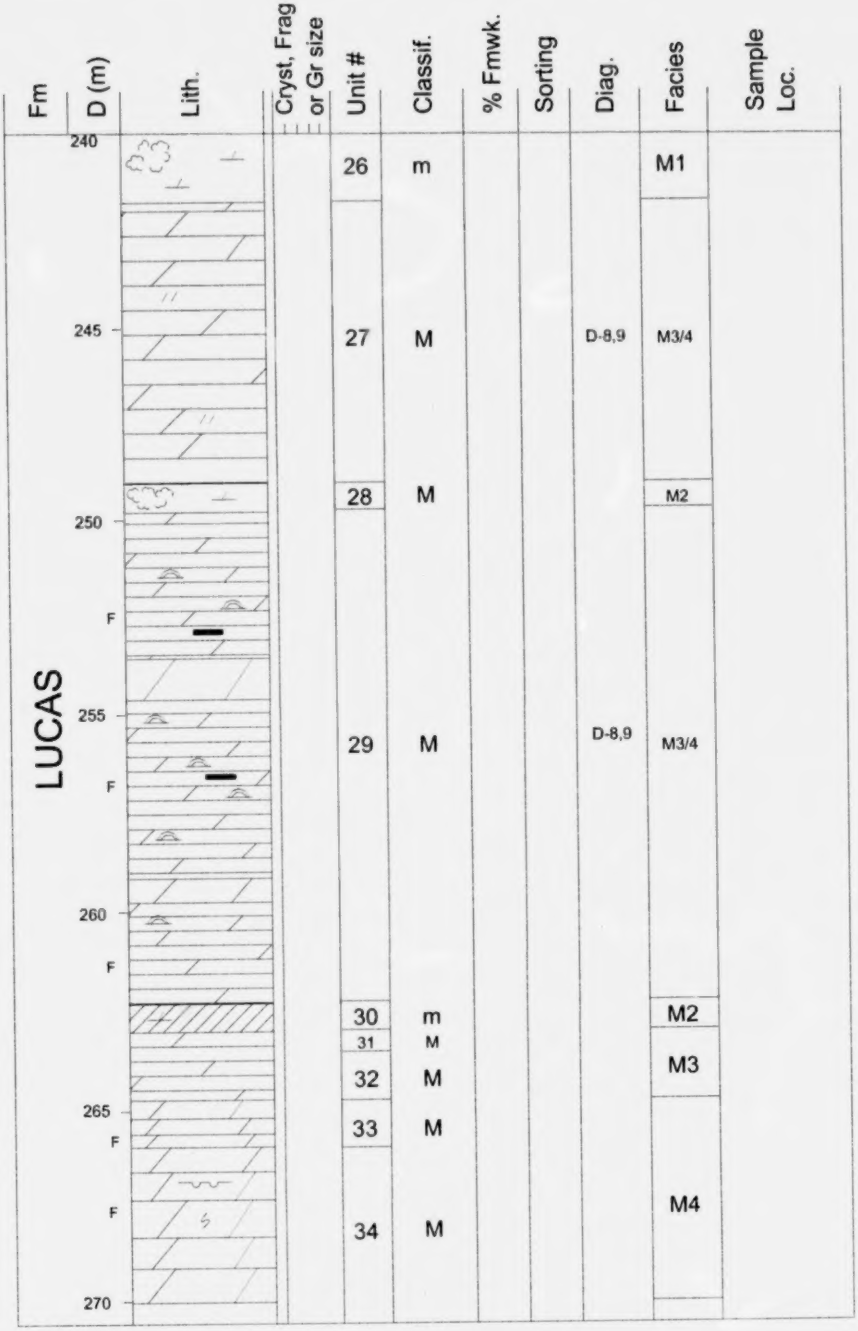
MOE Deep OBS #1
Lambton Co., Sarnia Twp.
Continued

(#15)

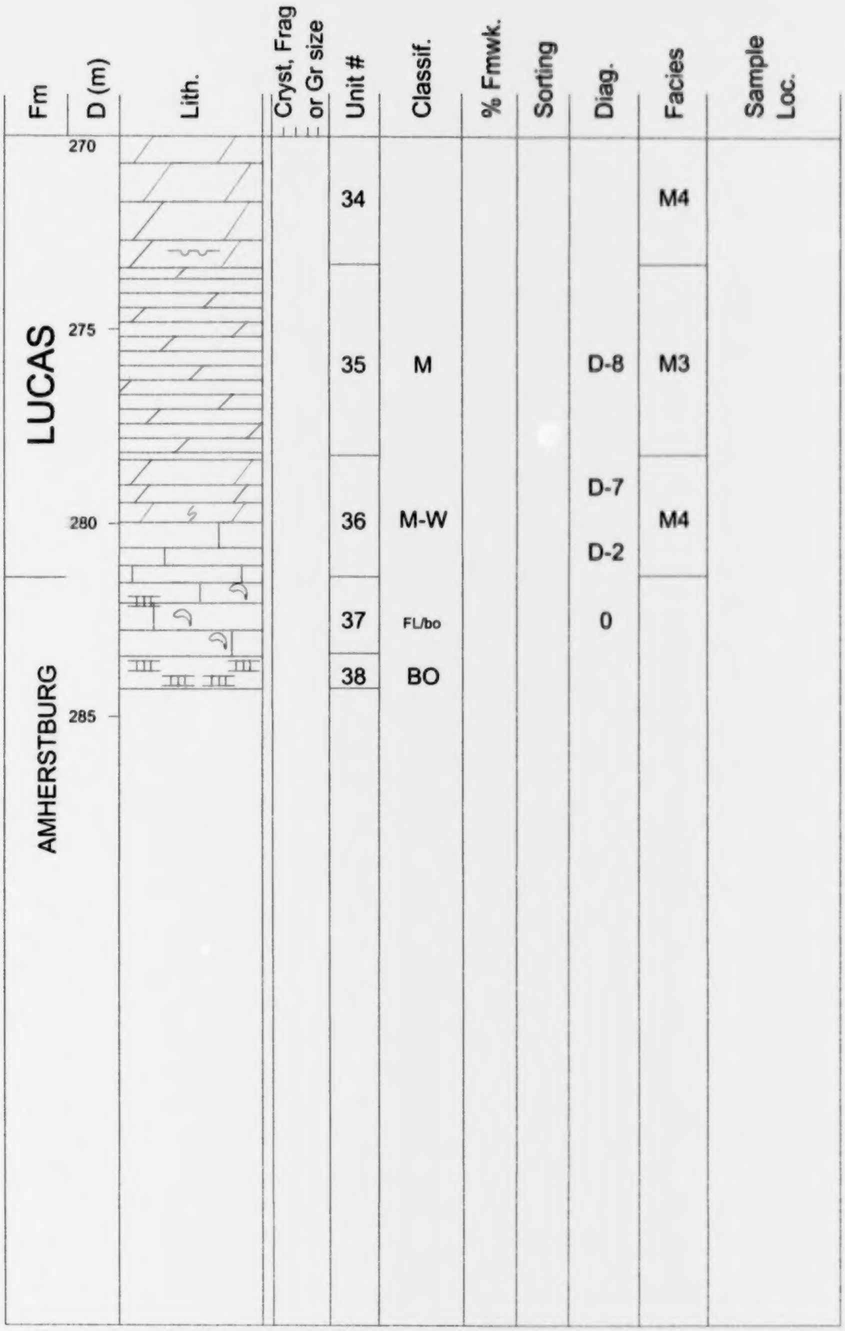

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
210
F
215
F
X
X
X
V X
220
X
225
230
235
240
13 m M1
14 M
15 M M4
16 W-M 1,2
17 M M2
18 M1
19 m M2
20 R M1
21 R
22 M D-9 M4
23 M M3
24 m M1
25 M D-8,9 M3/4
26 m M1

MOE Deep OBS #1
Lambton Co., Sarnia Twp.
Continued

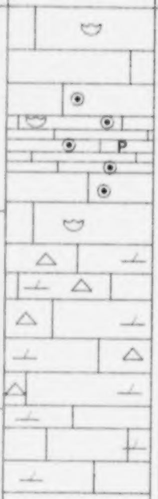
(#15)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
240
245
250
255
260
265
270
F
F
F
F
F
26
m
M1
27
M
D-8,9
M3/4
28
M
M2
29
M
D-8,9
M3/4
30
m
M2
31
M
32
M
M3
33
M
34
M
M4

MOE Deep OBS #1
Lambton Co., Sarnia Twp.
Continued (#15)

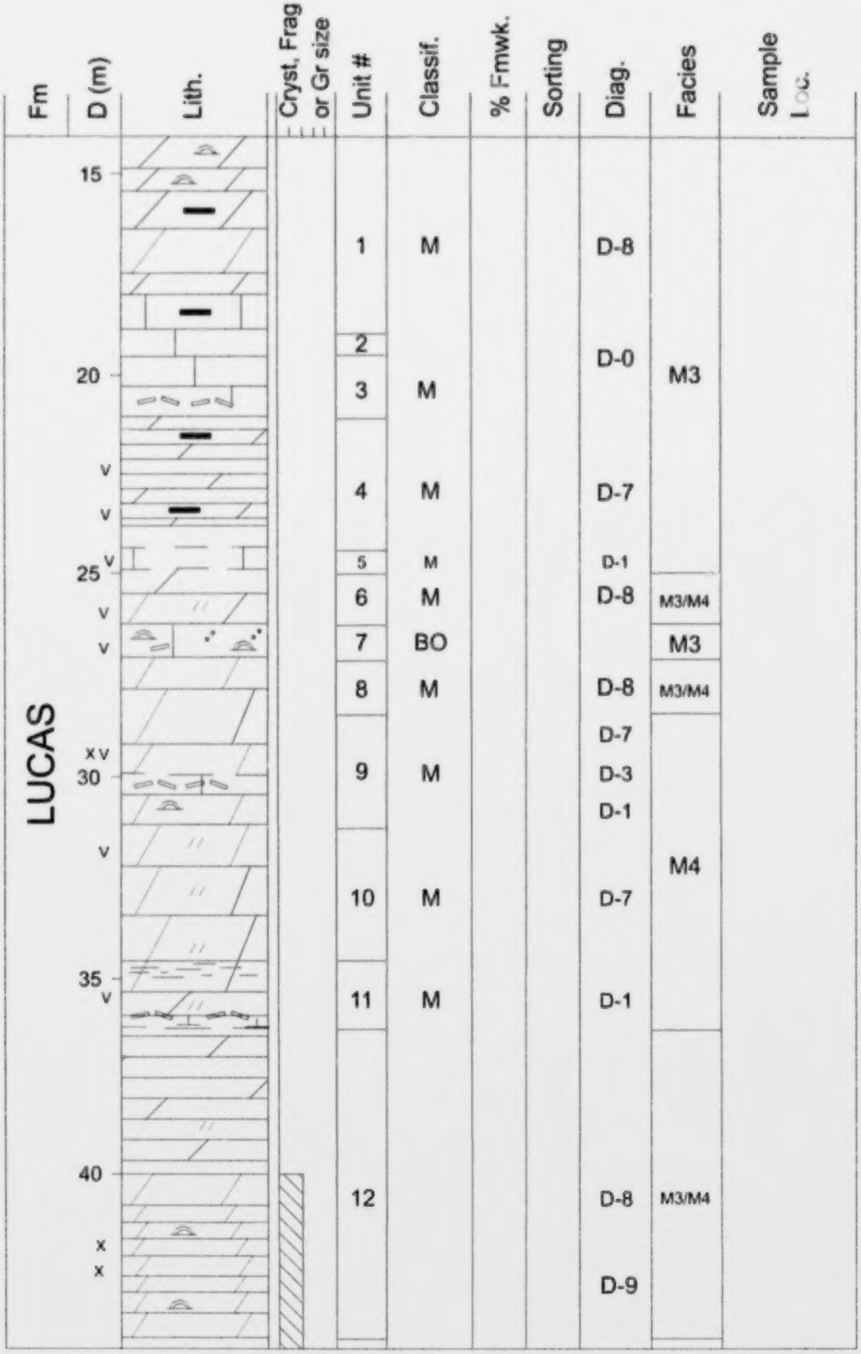

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
AMHERSTBURG
270
275
280
285
34
M4
35
M
D-8
M3
36
M-W
D-7
D-2
M4
37
FL/bo
0
38
BO

Lucas No. 1
Essex Co., Mersea Twp. (#16)



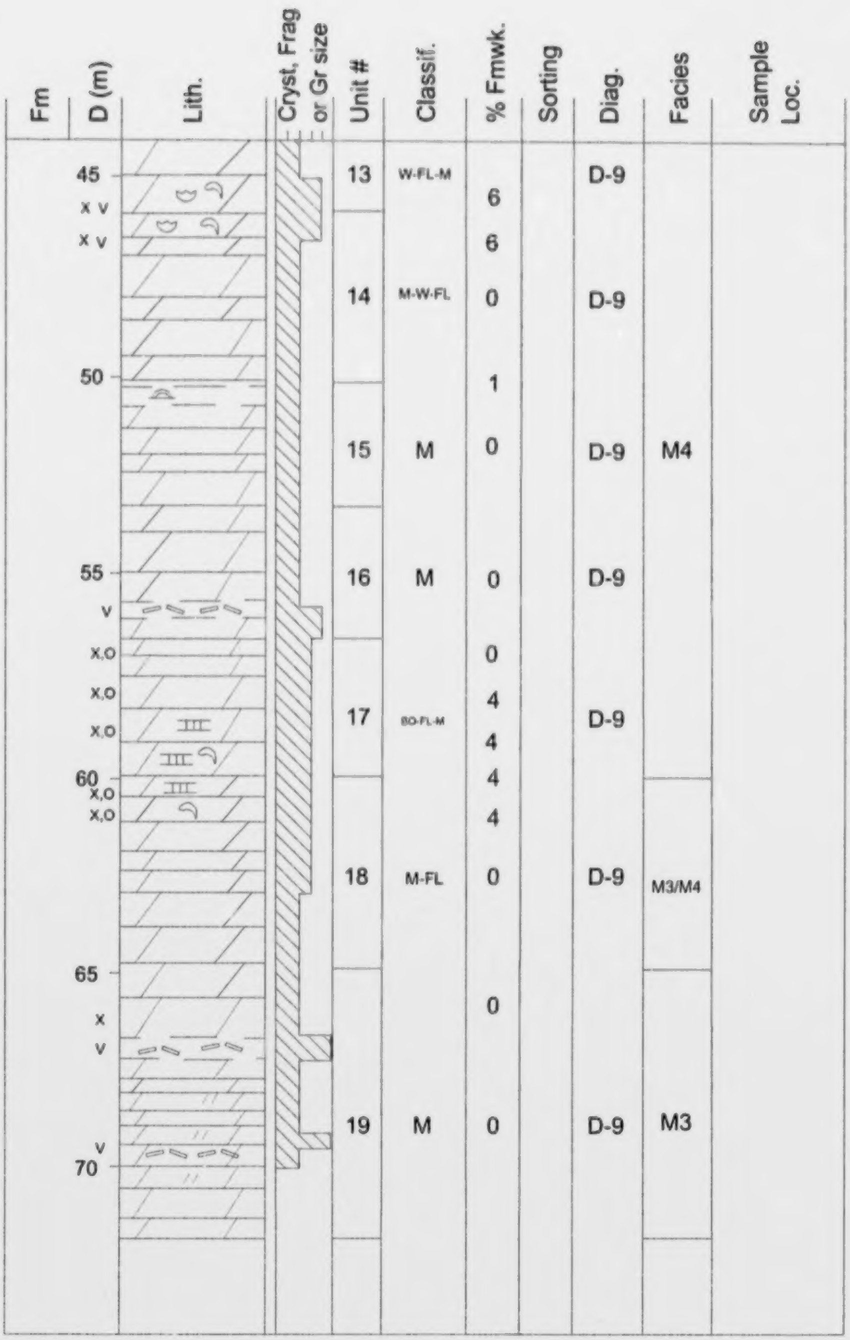
Fm	D (m)	Lith.	Cryst, Frag or Gr size	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE	20			1	W					
				2	W/P-R	7 7 7	P P P			
	25			3	W	1		D-1		
	F F			4	W	1		D-3		
	30 F XF XF			5	M-W	1		D-3		

Domtar Test #3
Huron Co., Goderich Twp. (#17)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
15
20
25
30
35
40
v
v
v
v
v
xv
v
v
x
x
1 M D-8
2
D-0
3 M
M3
4 M D-7
5 M D-1
6 M D-8 M3/M4
7 BO M3
8 M D-8 M3/M4
D-7
9 M D-3
D-1
M4
10 M D-7
11 M D-1
12 D-8 M3/M4
D-9

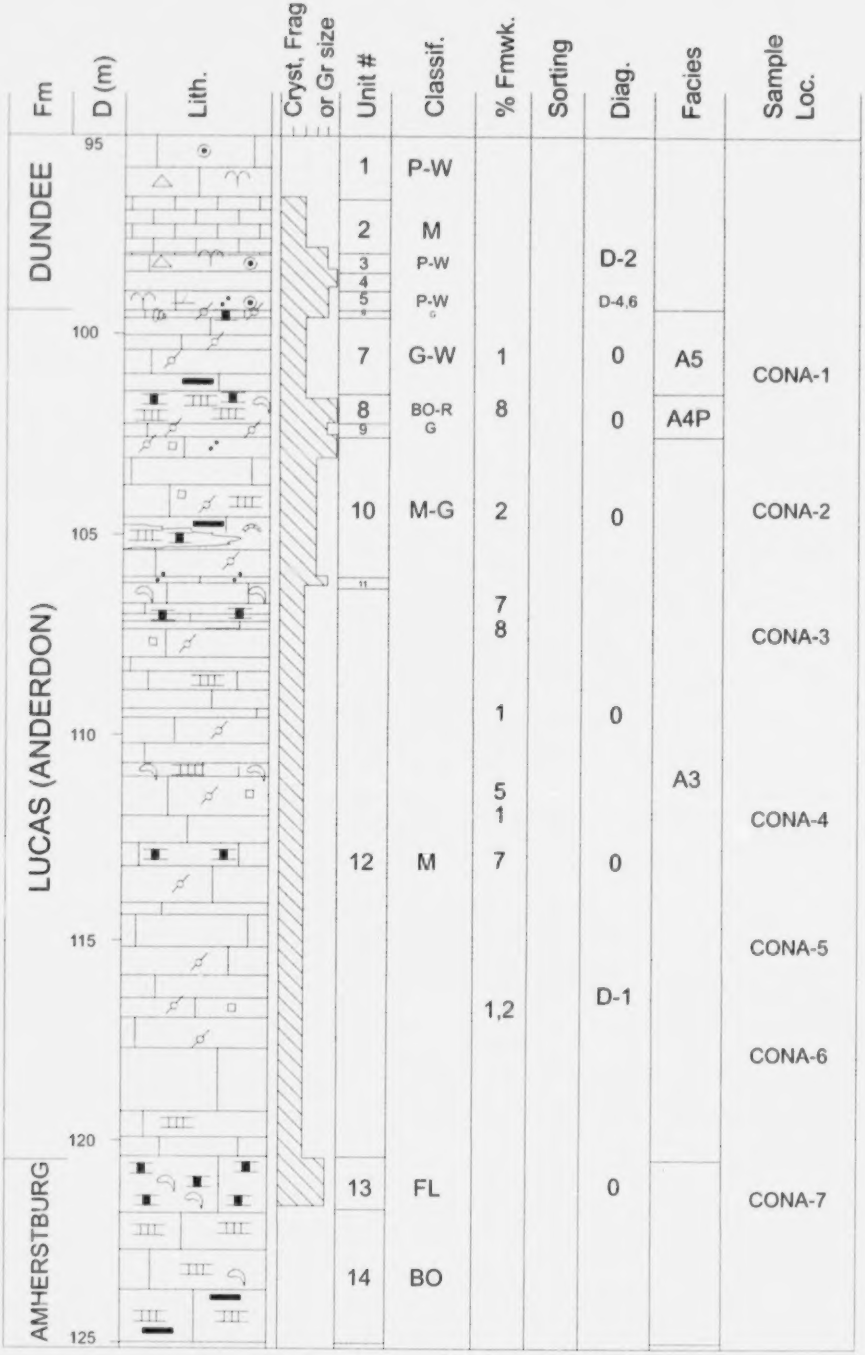
Domtar Test #3
Huron Co., Goderich Twp.
Continued

(#17)

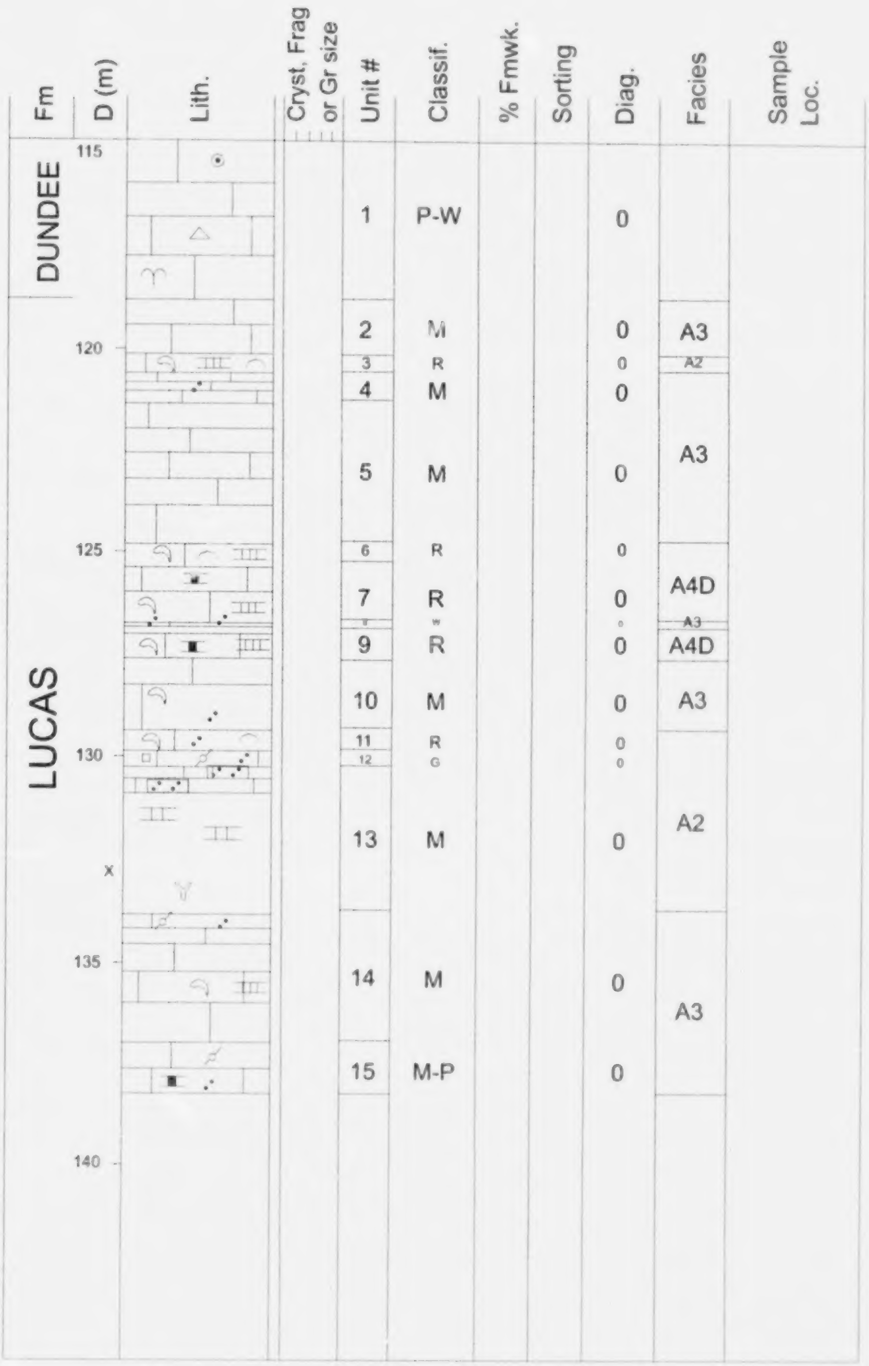

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
45
x v
x v
50
55
v
x,o
x,o
x,o
60
x,o
x,o
65
x
v
v
70
13
W-FL-M
6
6
D-9
14
M-W-FL
0
D-9
1
15
M
0
D-9
M4
16
M
0
D-9
0
4
17
BO-FL-M
4
D-9
4
4
18
M-FL
0
D-9
M3/M4
0
19
M
0
D-9
M3

Consumers Amoro 13076
Lake Erie

(#18)

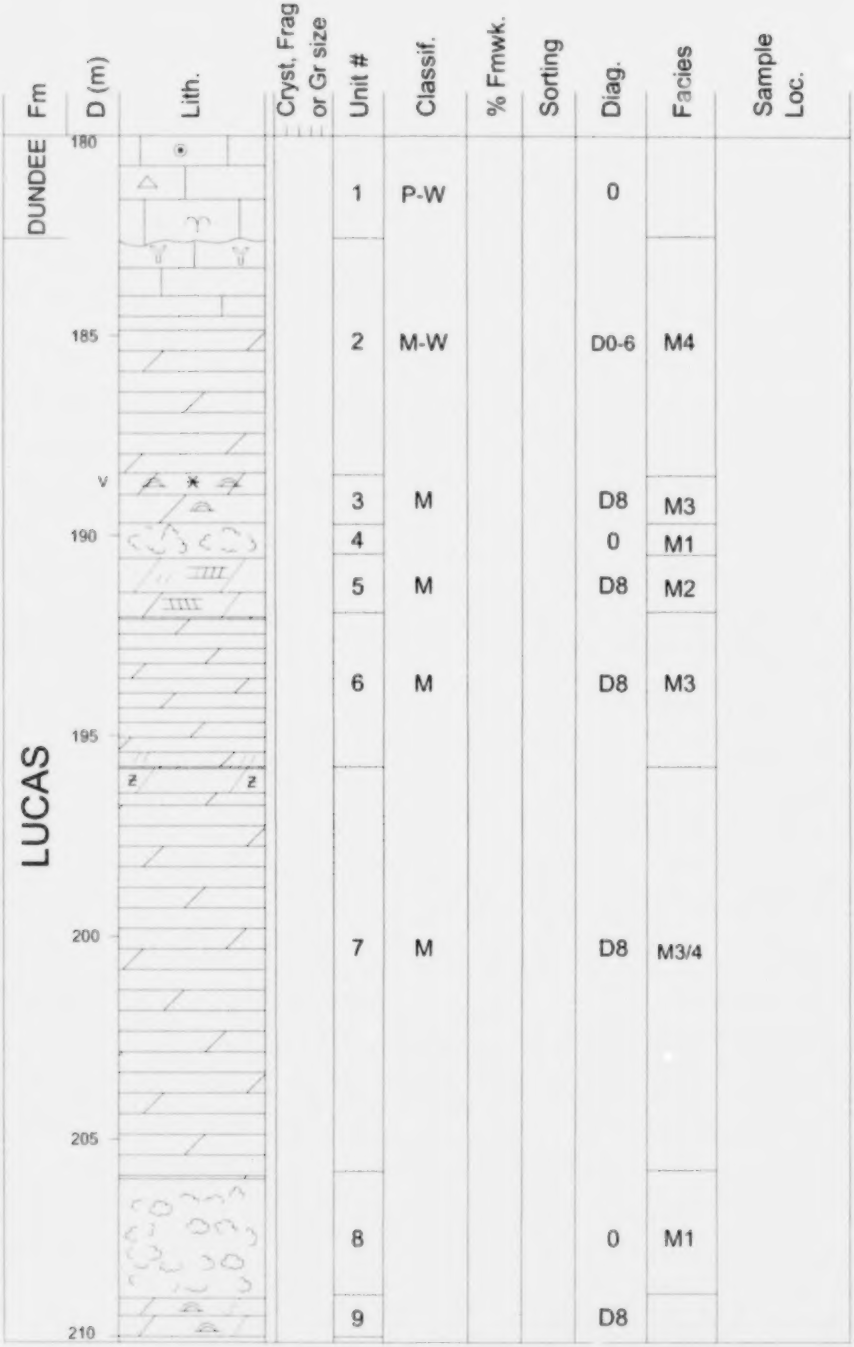

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS (ANDERDON)
AMHERSTBURG
95
100
105
110
115
120
125
1
P-W
2
M
3
P-W
D-2
4
5
P-W
D-4,6
7
G-W
1
0
A5
CONA-1
8
BO-R
8
0
A4P
9
G
10
M-G
2
0
CONA-2
11
7
8
CONA-3
1
0
A3
5
1
CONA-4
12
M
7
0
CONA-5
D-1
1,2
CONA-6
13
FL
0
CONA-7
14
BO

Leesa-Imperial Brooke 1-13-I
Lambton Co., Brooke Twp. (#19)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
DUNDEE
LUCAS
115
120
125
130
135
140
x

Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
1	P-W			0		
2	M			0	A3	
3	R			0	A2	
4	M			0	A3	
5	M			0		
6	R			0	A4D	
7	R			0		
8	W			0	A3	
9	R			0	A4D	
10	M			0	A3	
11	R			0	A2	
12	G			0		
13	M			0		
14	M			0	A3	
15	M-P			0		

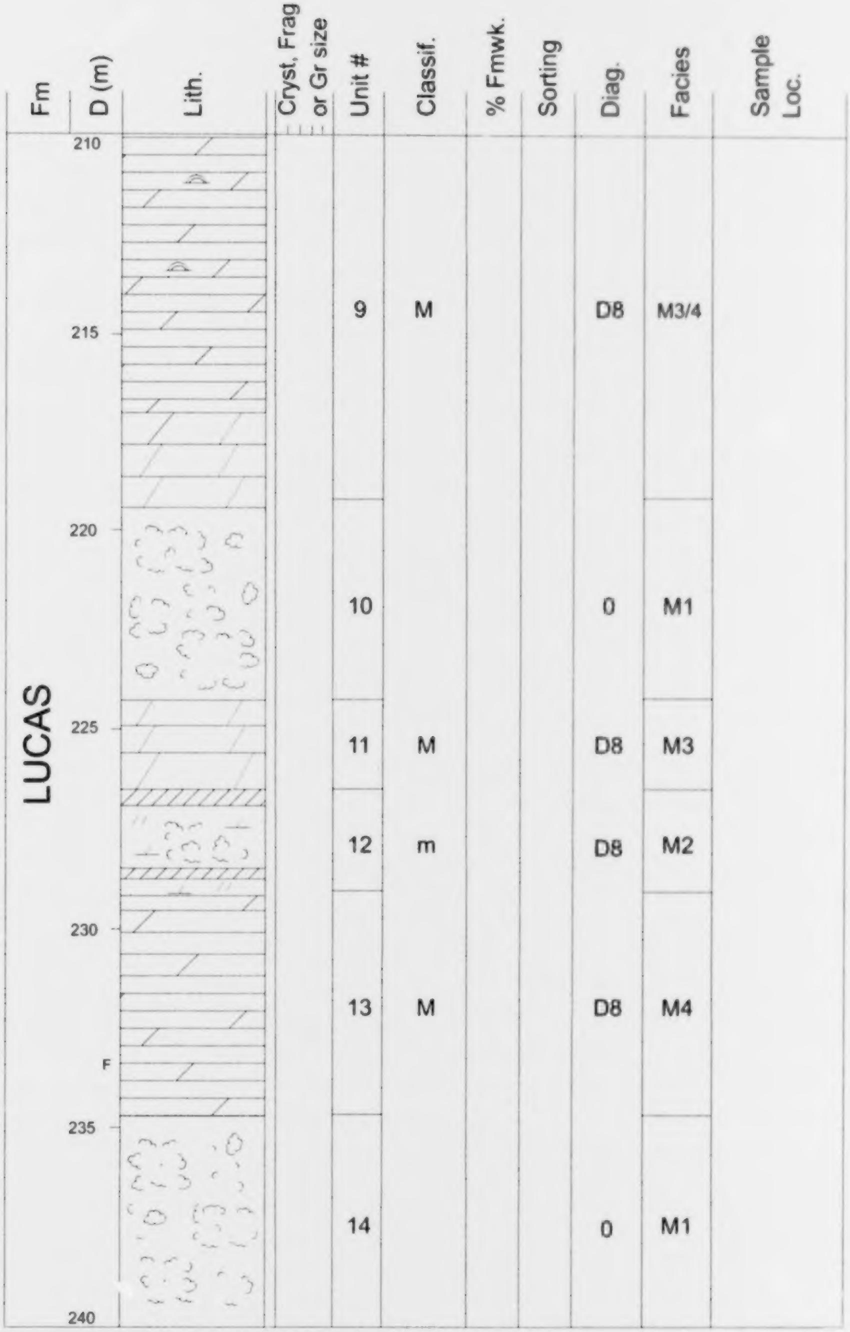
Imperial #700 - Ref. 1
Lambton Co., Sarnia Twp. (#20)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
DUNDEE
LUCAS
180
185
v
190
195
200
205
210

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE	1	P-W			0		
LUCAS	2	M-W			D0-6	M4	
	3	M			D8	M3	
	4				0	M1	
	5	M			D8	M2	
	6	M			D8	M3	
	7	M			D8	M3/4	
	8				0	M1	
	9				D8		

Imperial #700 - Ref. 1
Lambton Co., Sarnia Twp.
Continued

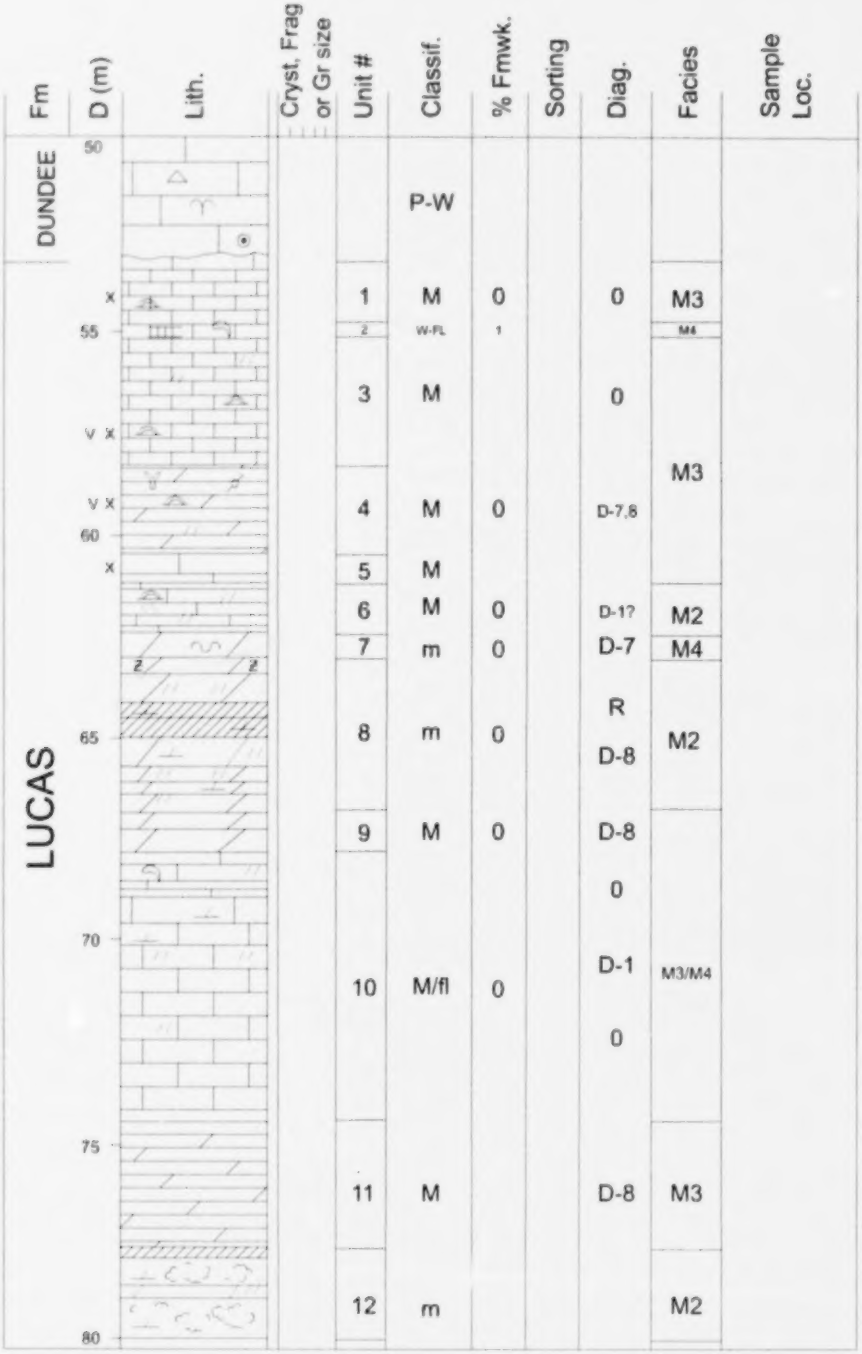
(#20)



Fm
D (m)
Lith.
LUCAS
210
215
220
225
230
F
235
240

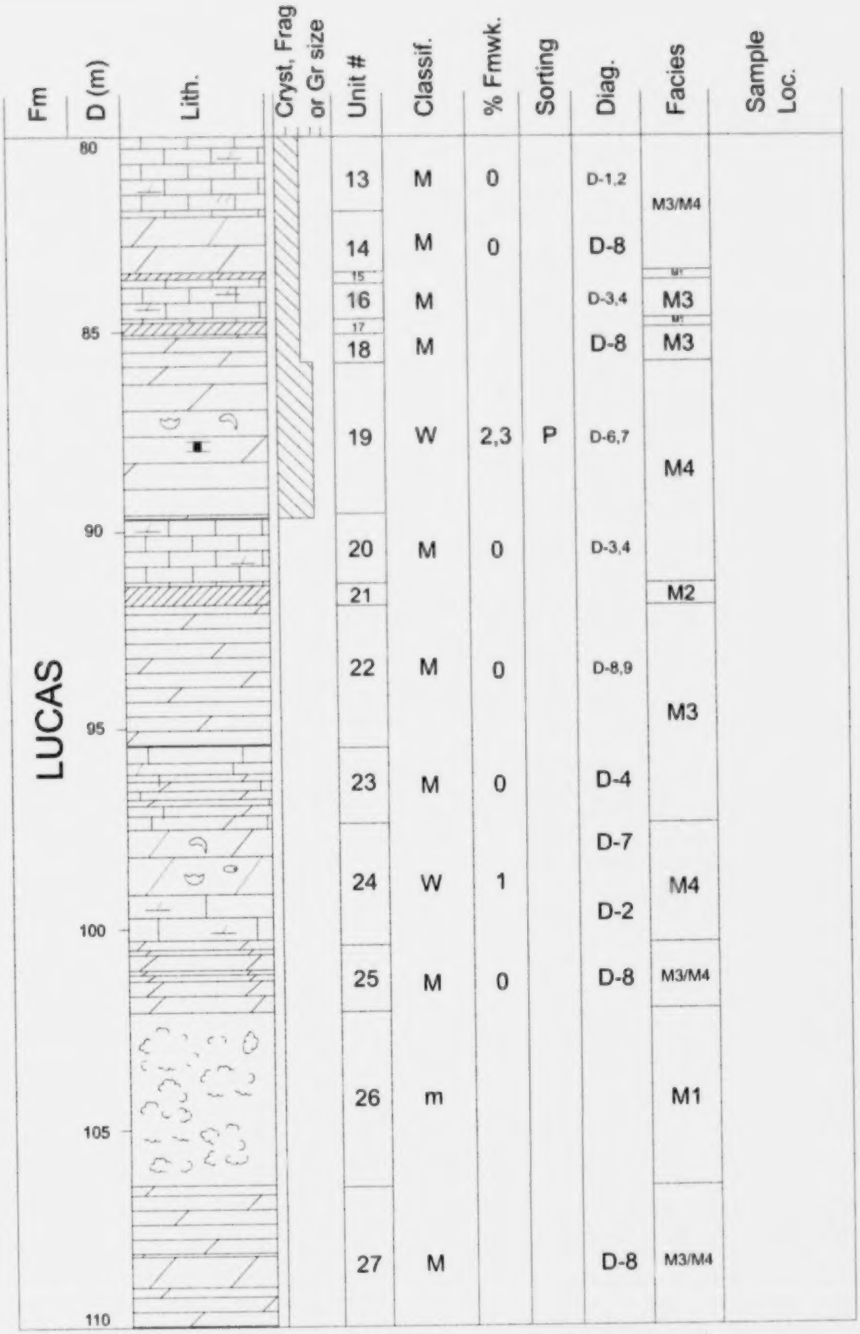
Cryst, Frag or Gr size	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
	9	M			D8	M3/4	
	10				0	M1	
	11	M			D8	M3	
	12	m			D8	M2	
	13	M			D8	M4	
	14				0	M1	

Imperial #809
Middlesex Co., McGillivray Twp. (#21)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
DUNDEE
LUCAS
50
55
60
65
70
75
80
x
v x
v x
x

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE		P-W					
LUCAS	1	M	0		0	M3	
	2	W-FL	1			M4	
	3	M			0	M3	
	4	M	0		D-7,8		
	5	M					
	6	M	0		D-1?	M2	
	7	m	0		D-7	M4	
	8	m	0		R D-8	M2	
	9	M	0		D-8	M3/M4	
	10	M/fl	0		0 D-1 0		
	11	M			D-8	M3	
	12	m				M2	

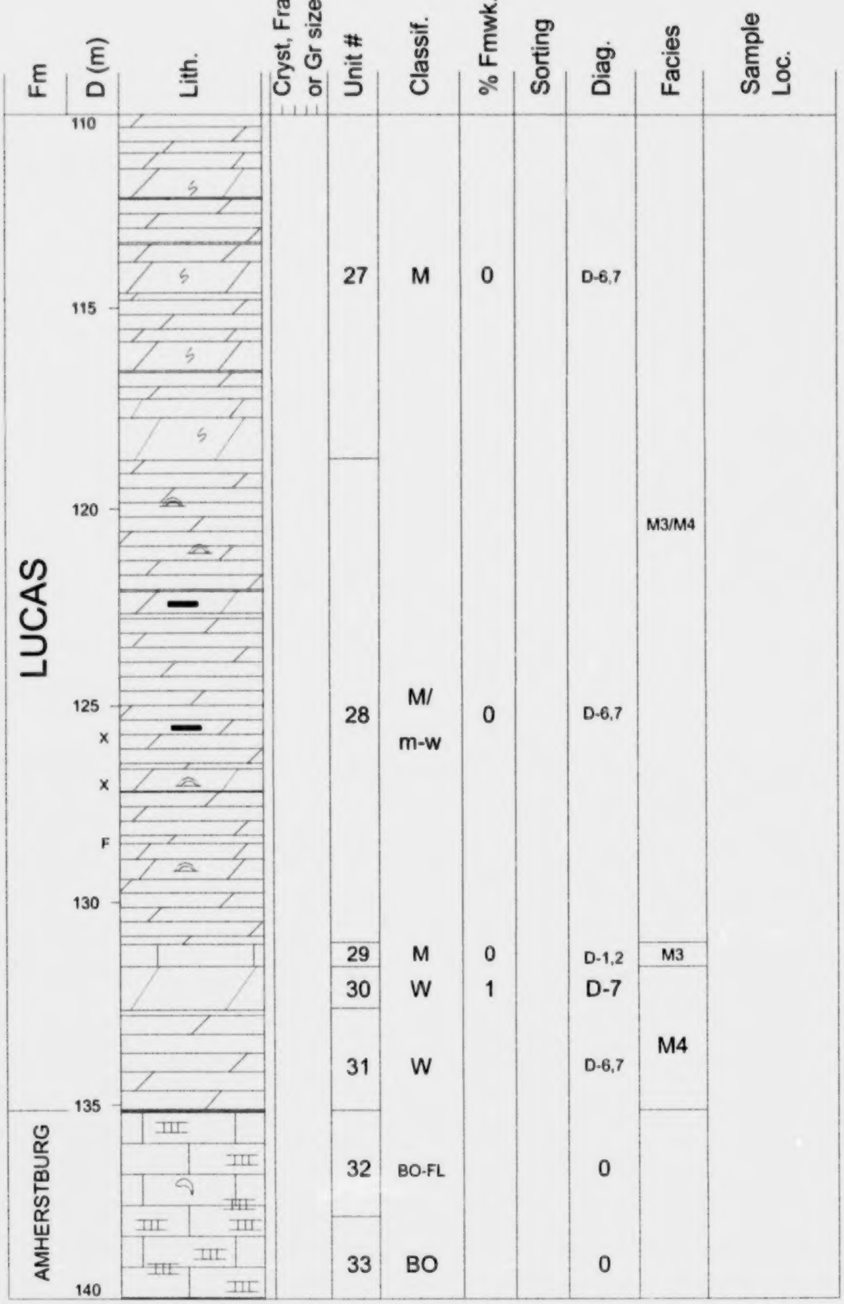
Imperial #809
Middlesex Co., McGillivray Twp.
Continued (#21)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
LUCAS
80
85
90
95
100
105
110

Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
13	M	0		D-1,2	M3/M4	
14	M	0		D-8		
15					[illegible]	
16	M			D-3,4	M3	
17					[illegible]	
18	M			D-8	M3	
19	W	2,3	P	D-6,7	M4	
20	M	0		D-3,4		
21					M2	
22	M	0		D-8,9	M3	
23	M	0		D-4		
24	W	1		D-7 D-2	M4	
25	M	0		D-8	M3/M4	
26	m				M1	
27	M			D-8	M3/M4	

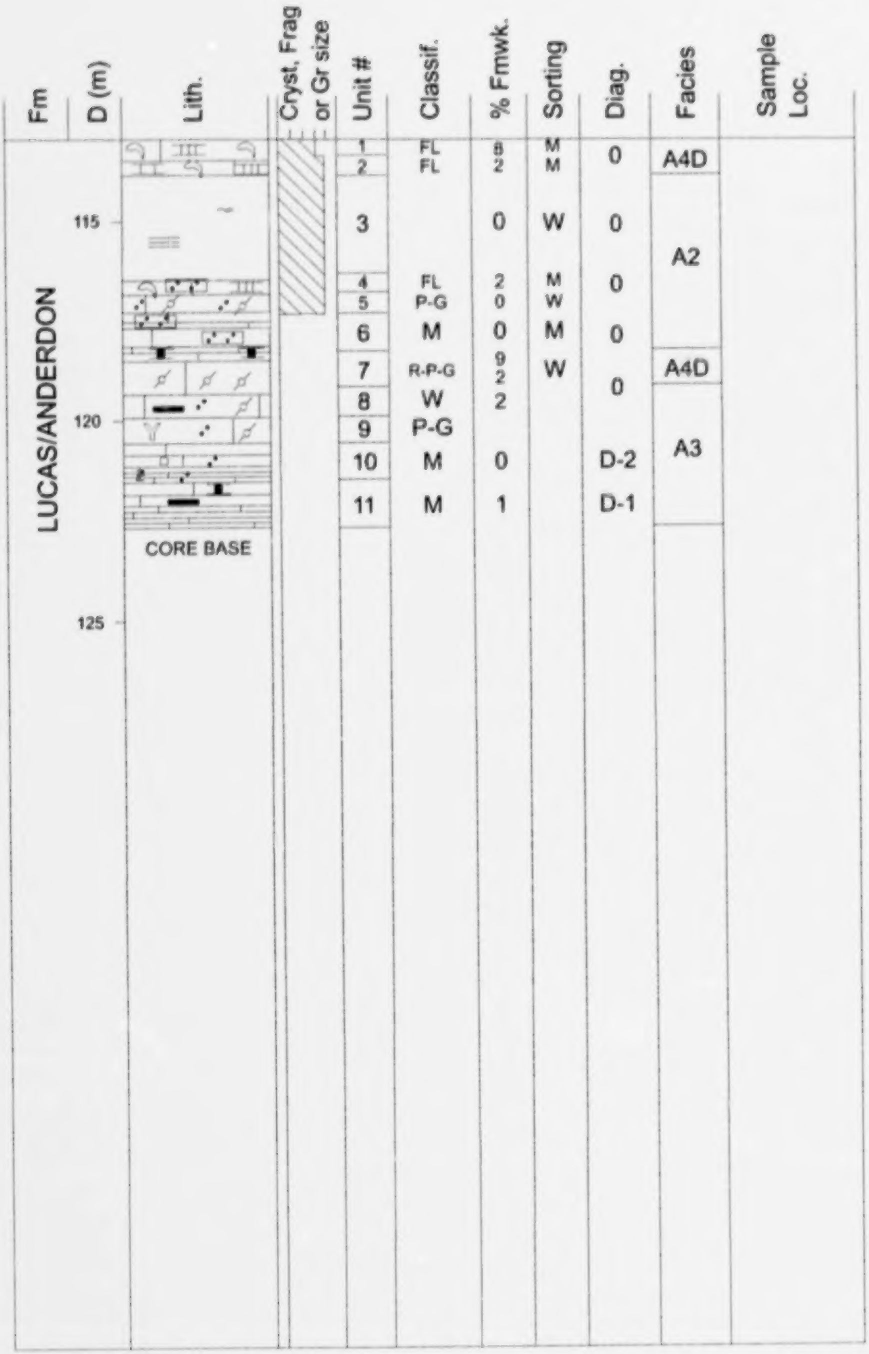
Imperial #809
Middlesex Co., McGillivray Twp.
Continued

(#21)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
LUCAS
AMHERSTBURG
110
115
120
125
x
x
F
130
135
140

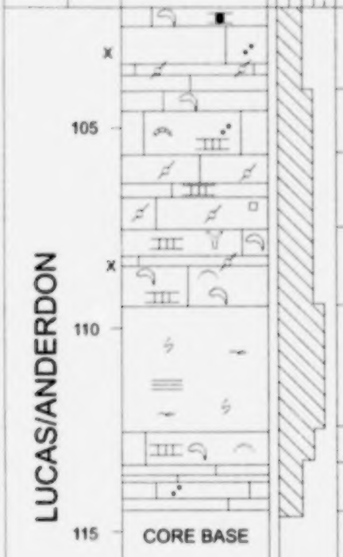
Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
LUCAS	27	M	0		D-6,7	M3/M4	
	28	M/ m-w	0		D-6,7		
	29	M	0		D-1,2	M3	
	30	W	1		D-7	M4	
	31	W			D-6,7		
AMHERSTBURG	32	BO-FL			0		
	33	BO			0		

Mitchell #3
Middlesex Co., Mosa Twp. (#22)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
115
120
125
LUCAS/ANDERDON
CORE BASE

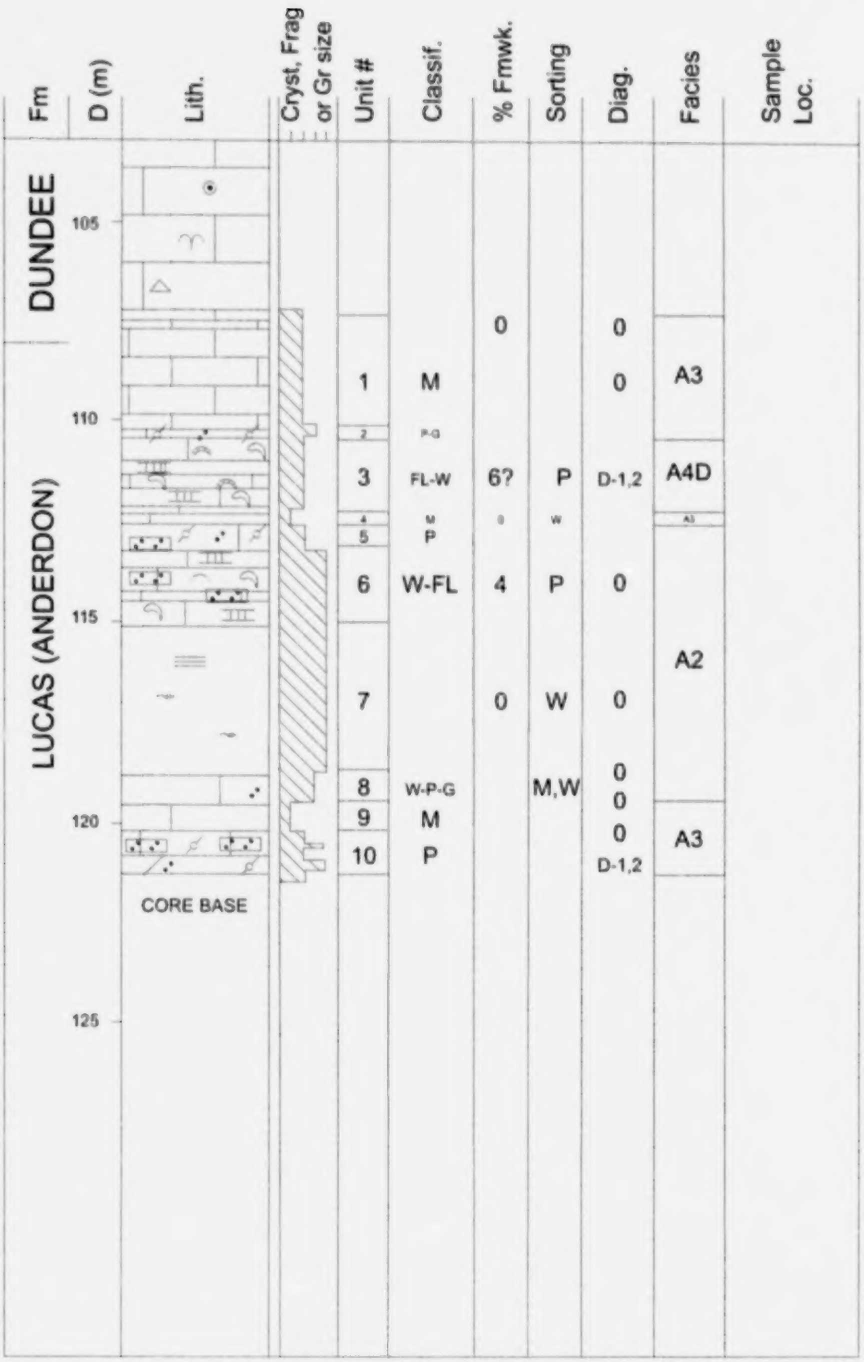
Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
1	FL	8	M	0	A4D	
2	FL	2	M			
3		0	W	0	A2	
4	FL	2	M	0		
5	P-G	0	W			
6	M	0	M	0		
7	R-P-G	9 2	W	0	A4D	
8	W	2			A3	
9	P-G					
10	M	0		D-2		
11	M	1		D-1		

Walker #502
Middlesex Co., Mosa Twp. (#23)


LUCAS/ANDERDON
x
105
x
110
115
CORE BASE
120

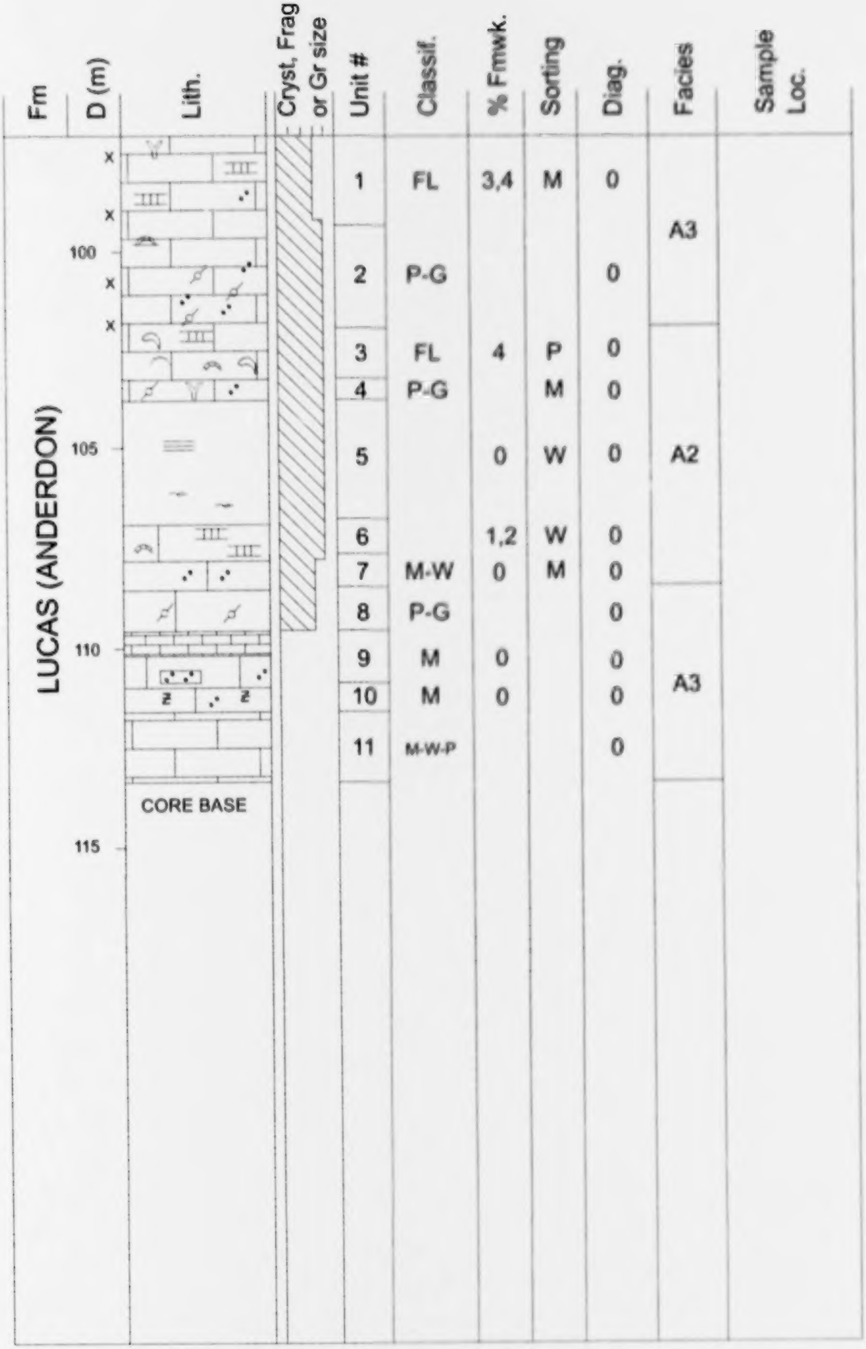
Fm	D (m)	Lith.	Cryst, Frag or Gr size	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
LUCAS/ANDERDON				1	W/g	1	W	0		
				2	FL	2	M,P	0	A3	
				3	P-G	1,2	W	0		
				4	FL	5	P	0	A4	
				5		0	W	0	A2	
				6	FL-W			0	A4D	
				7	M			0	A3	

Allegany Prod. W. 112
Middlesex Co., Mosa Twp. (#24)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS (ANDERDON)
105
110
115
120
125
0
0
1
M
0
A3
2
P-G
3
FL-W
6?
P
D-1,2
A4D
4
M
0
W
A3
5
P
6
W-FL
4
P
0
A2
7
0
W
0
8
W-P-G
M,W
0
9
M
0
10
P
0
D-1,2
A3
CORE BASE

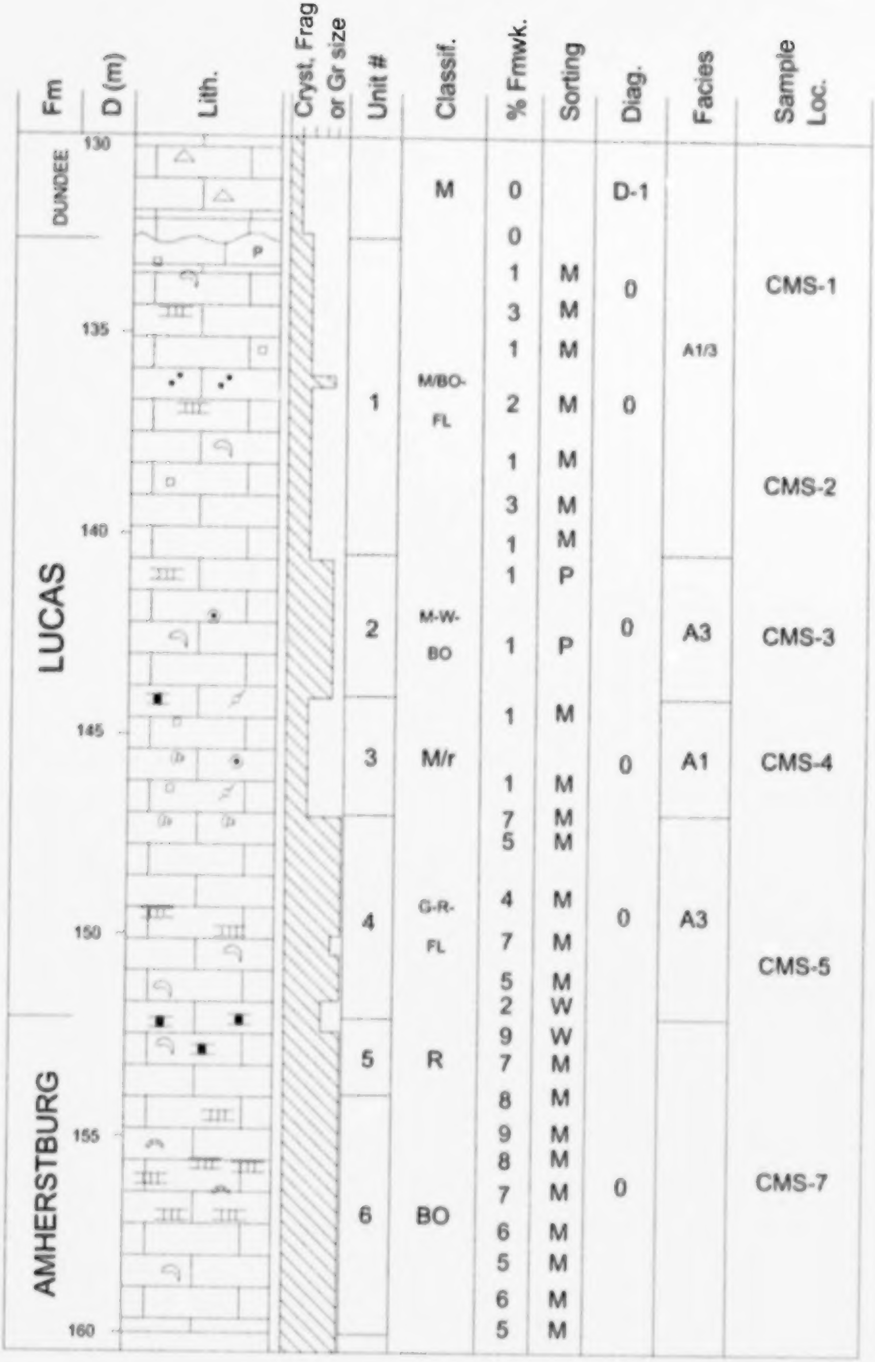
Secord 601
Middlesex Co., Mosa Twp.

(#25)

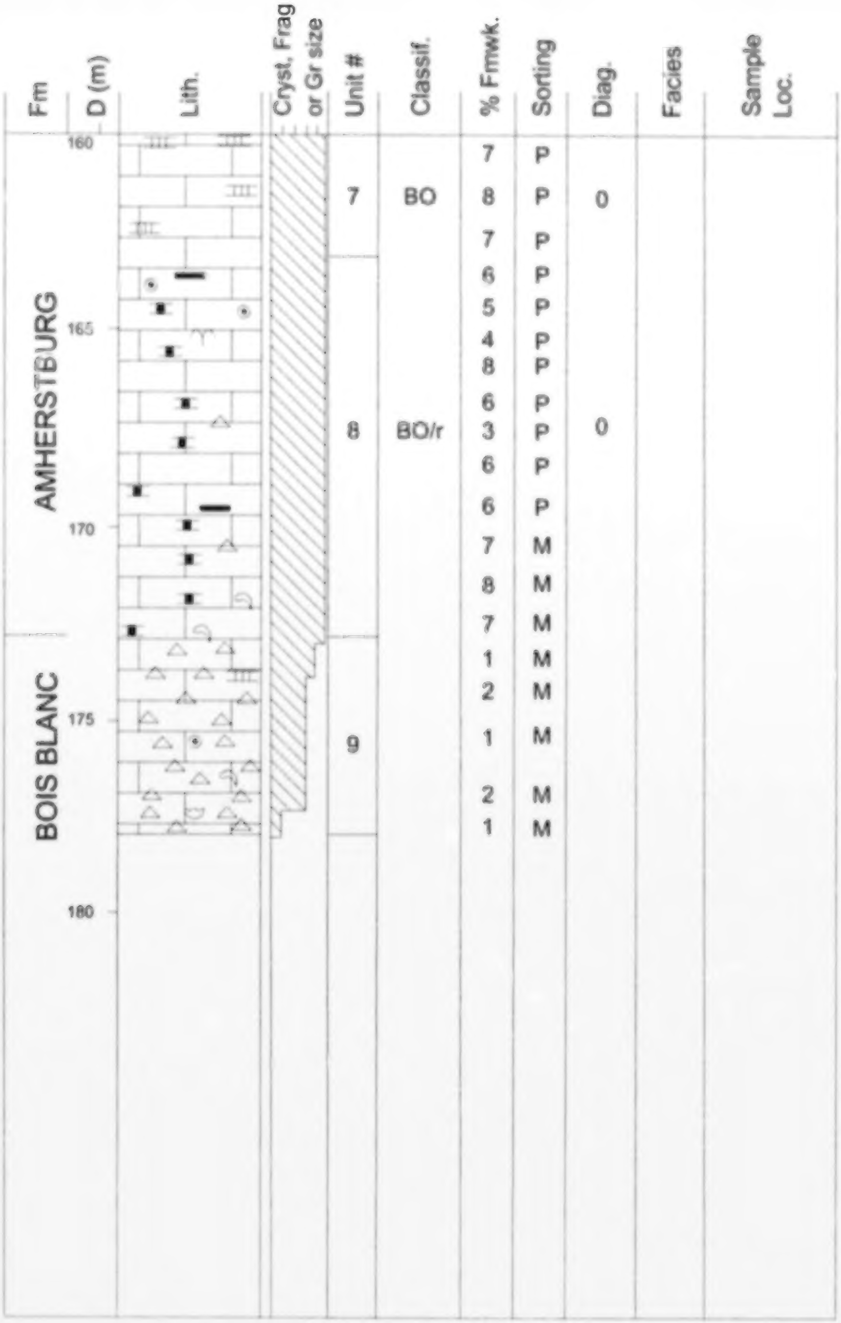

Fm
D (m)
Lith.
Cryst, Frag or Gr size
LUCAS (ANDERDON)
100
105
110
115
CORE BASE

Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
1	FL	3,4	M	0	A3	
2	P-G			0		
3	FL	4	P	0	A2	
4	P-G		M	0		
5		0	W	0		
6		1,2	W	0		
7	M-W	0	M	0		
8	P-G			0	A3	
9	M	0		0		
10	M	0		0		
11	M-W-P			0		

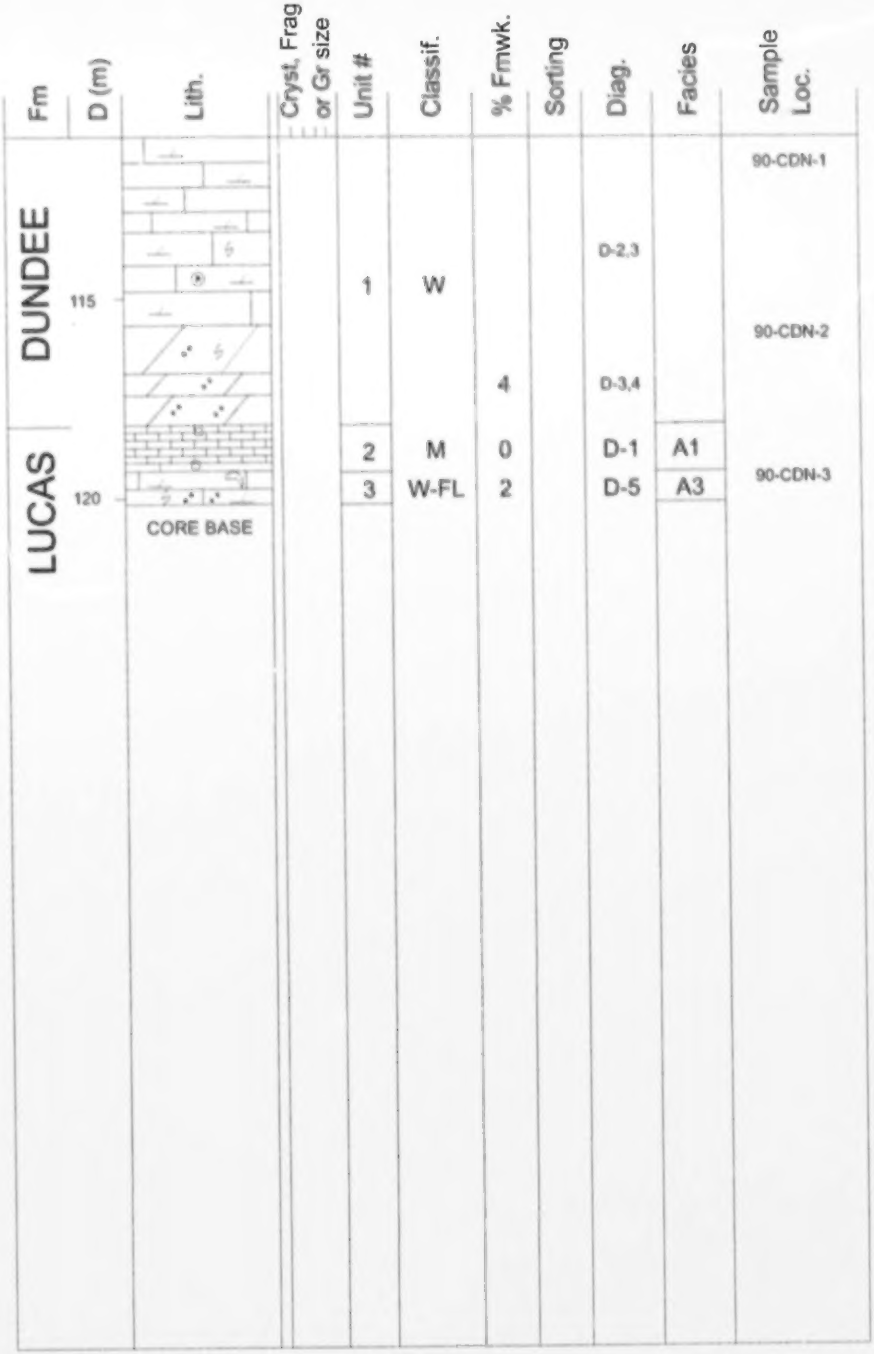
OGS-82-3
Elgin Co., Yarmouth (#26)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
AMHERSTBURG
130
135
140
145
150
155
160
P
1
2
3
4
5
6
M
M/BO-FL
M-W-BO
M/r
G-R-FL
R
BO
0
0
1
3
1
2
1
3
1
1
1
1
1
7
5
4
7
5
2
9
7
8
9
8
7
6
5
6
5
M
M
M
M
M
M
M
P
P
M
M
M
M
M
M
M
W
W
M
M
M
M
M
M
M
M
M
D-1
0
0
0
0
0
0
A1/3
A3
A1
A3
CMS-1
CMS-2
CMS-3
CMS-4
CMS-5
CMS-7

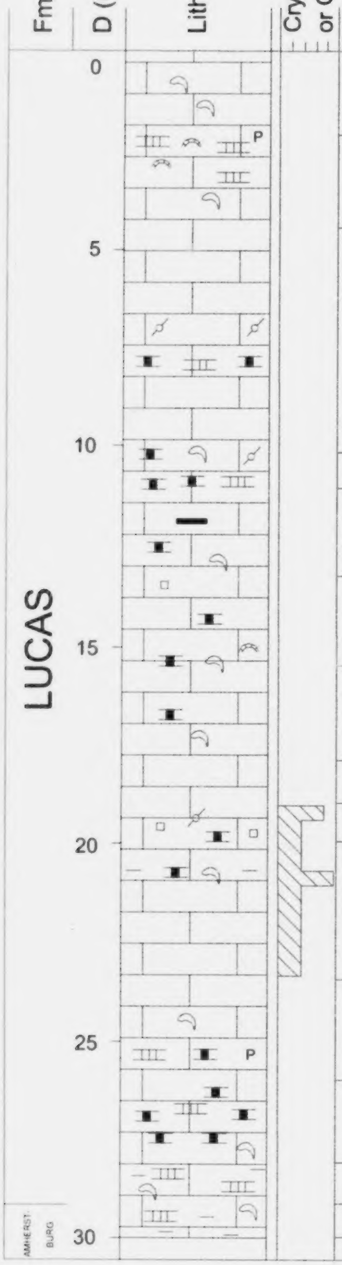
OGS-82-3
Elgin Co., Yarmouth Twp.
Continued (#26)



Cdnoxy Rodney 5-30
Elgin Co., Aldborough Twp. (#27)

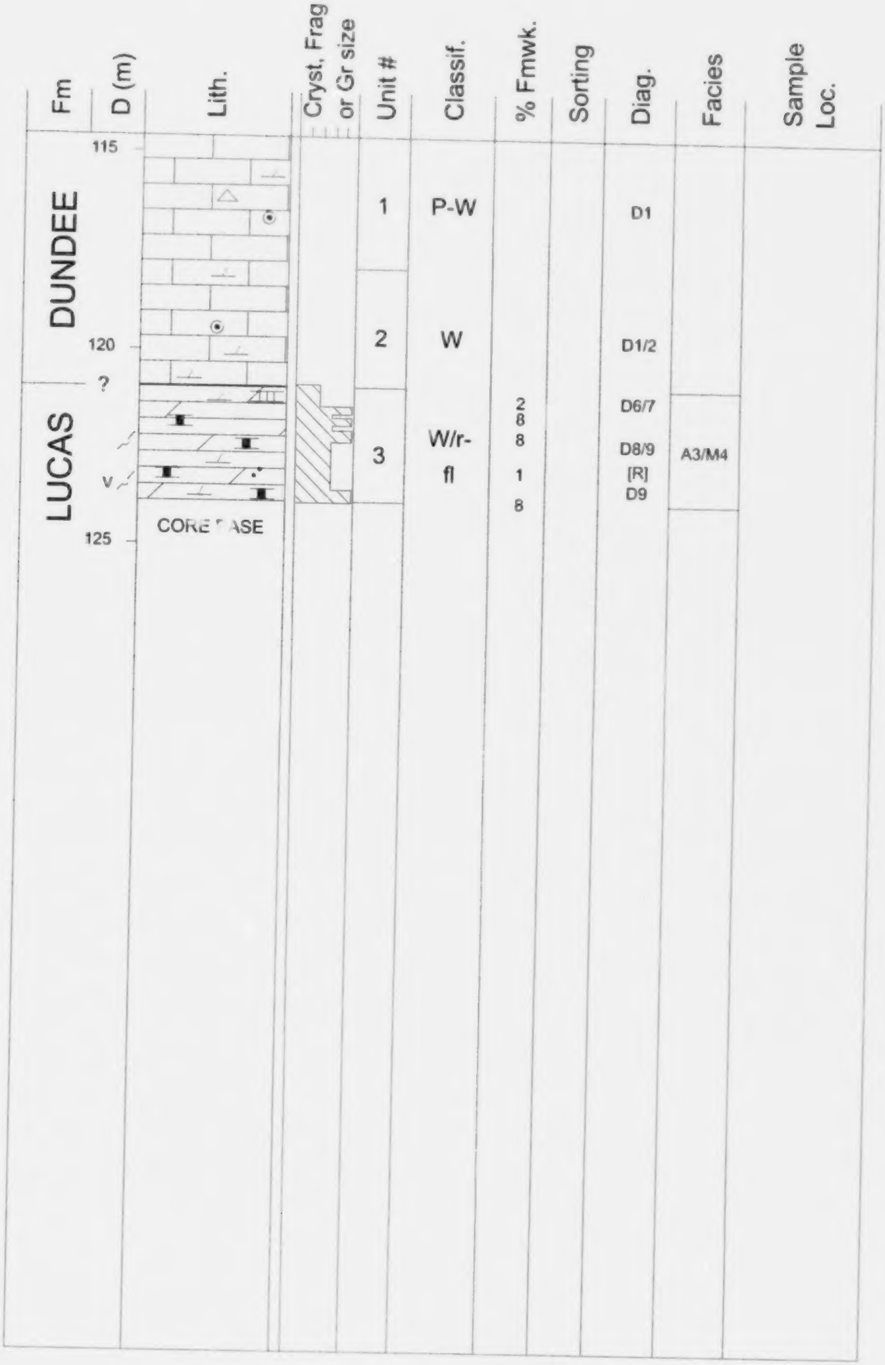

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
115
120
CORE BASE
1
W
4
D-2,3
D-3,4
2
M
0
D-1
A1
3
W-FL
2
D-5
A3
90-CDN-1
90-CDN-2
90-CDN-3

Canada Cement Lafarge 85-17
Oxford Co., W. Zorra Twp. (#28)

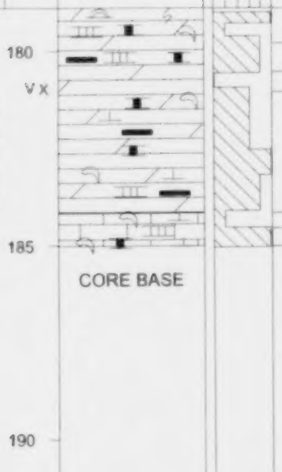

Fm
D (m)
Lith.
Cryst, Frag or Gr size
LUCAS
AMHERST-BURG
0
5
10
15
20
25
30
P
P

Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
1	M-W			R-3?	A3	CCL-1
2	W-FL- BI-FR			R-2?	A4P	CCL-2
3	M/ w-m	1		R-3?	A3	CCL-3 CCL-4
4	R-FL/ p	4 7		R-3?	A4D	
5	M				A3	CCL-5
6	M	0 6		R-3?		CCL-6
7	W-FL	2		R-3?		
8	M-W	0				CCL-7
9	FL-P	1	W			
10	M-W/ fl	2,3		R-3?		CCL-8
11	W-P-FL	4	M	R-3?		CCL-9
12	R-BO-FL	7,8			A4D	CCL-10
13	BO-FL	7		R-3?		
14	BO-FL	6				

Cdnoxy Rodney 6-18
Elgin Co., Aldborough Twp. (#33)

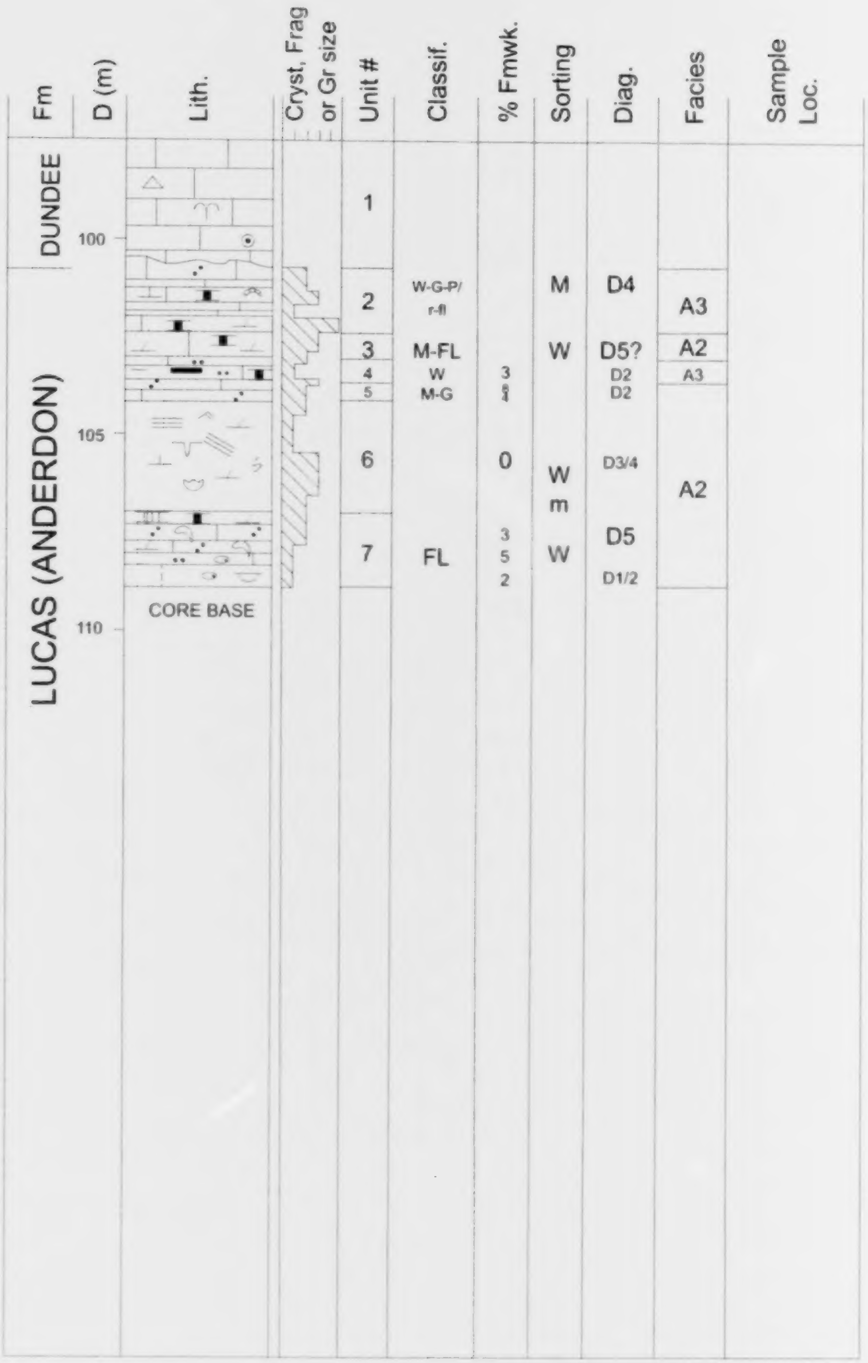

Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
115
120
?
125
DUNDEE
LUCAS
CORE BASE
1
P-W
D1
2
W
D1/2
3
W/r-fl
28818
D6/7
D8/9
[R]
D9
A3/M4

Brett
Kent Co., Camden Gore Twp. (#38)


D (m)
Lith.
Cryst, Frag or Gr size
180
V X
185
190
CORE BASE

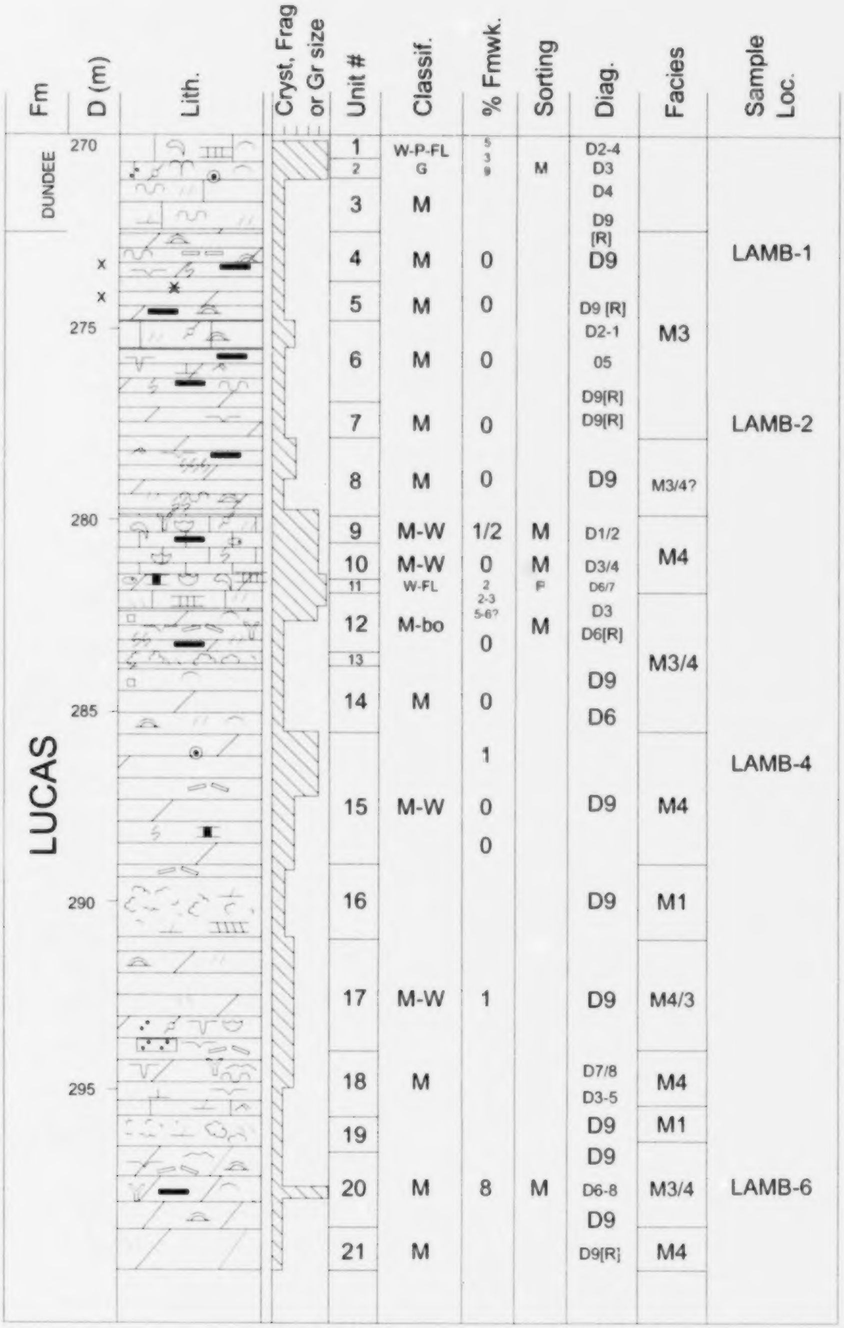
Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
LUCAS	1	M/fl	0 2 0		D8[R]	M3/A3	
	2	FL/r	3/4		D8/9[8]	A3	
	3	M	0		D8[R]		
	4	BO-FL/r	2 3 4 7 4		D6/7	A1/A3	
	5	M	1		D5-7	A3	
	6	BO	6		D5-7	A3/A4P	

Leesa-Dawn 19-XIII
Lambton Co., Dawn Twp. (#46)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS (ANDERDON)
100
105
110
CORE BASE
1
2
W-G-P/ r-fl
M
D4
A3
3
M-FL
W
D5?
A2
4
W
3
D2
A3
5
M-G
D2
6
0
W m
D3/4
A2
7
FL
3 5 2
W
D5
D1/2

OGS-82-1
Lambton Generating Station
(Courtright)

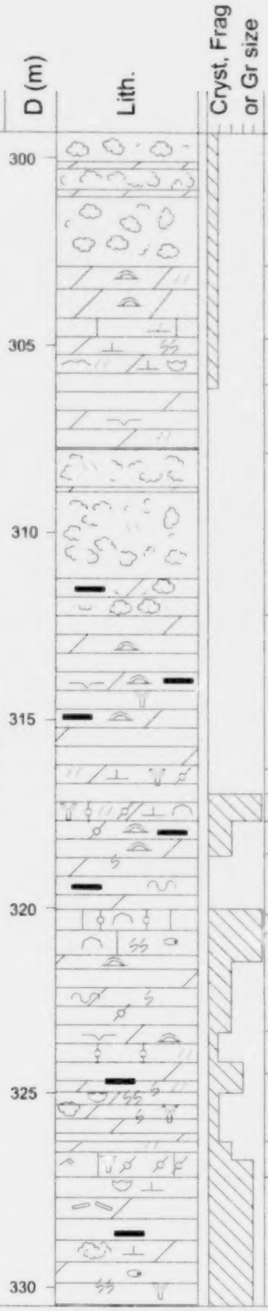
(#51)



Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
270
275
280
285
290
295
x
x
1
W-P-FL
5
D2-4
2
G
3
9
M
D3
3
M
D4
D9
[R]
4
M
0
D9
LAMB-1
5
M
0
D9 [R]
D2-1
M3
6
M
0
05
D9[R]
7
M
0
D9[R]
LAMB-2
8
M
0
D9
M3/4?
9
M-W
1/2
M
D1/2
10
M-W
0
M
D3/4
M4
11
W-FL
2
F
D6/7
2-3
5-6?
D3
12
M-bo
M
D6[R]
0
13
M3/4
D9
14
M
0
D6
1
LAMB-4
15
M-W
0
D9
M4
0
16
D9
M1
17
M-W
1
D9
M4/3
D7/8
18
M
M4
D3-5
19
D9
M1
D9
20
M
8
M
D6-8
M3/4
LAMB-6
D9
21
M
D9[R]
M4

OGS-82-1
Lambton Generating Station
(Courtright)
Continued

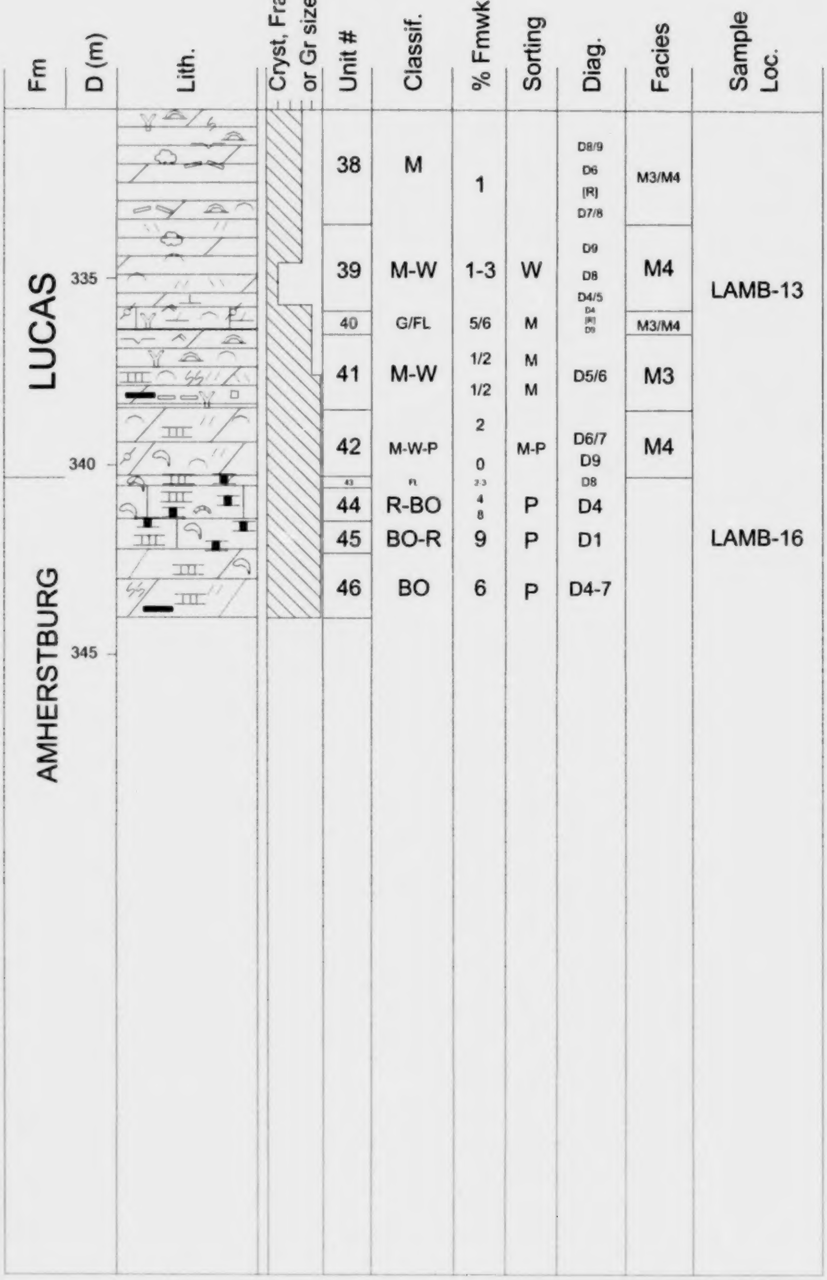
(#51)


D (m)
Lith.
Cryst, Frag or Gr size
300
305
310
315
320
325
330

Fm	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
LUCAS	22	m			D9	M1	
	23	M			D9	M3	
	24	M-W	1	M	D4/5 D6-8	M4	
	25	M	0		D9		LAMB-8
	26	m			D9	M1	
	27	M			D9	M3	LAMB-9
	28	M	1		D6-8	M2	
	29	G/P-FL	4-9		D3-9	M3/M4	LAMB-10
	30	M	1	W	D6/7	M3	
	31	M			D7	M4	
	32	G	8	M	D4		
	33	M	1 0		D3 D5 D7 D9	M3/4	LAMB-11
	34	G-M	6-7	W	D6-9		
	35	M-W	1 1		D6/7	M4	
	36	G	5-6 9	M W	D5/6 D1		
	37	M-W	1 1 1	M M	D6/7 D9 D6/7 D8		LAMB-12

OGS-82-1
Lambton Generating Station
(Courtright)
Continued

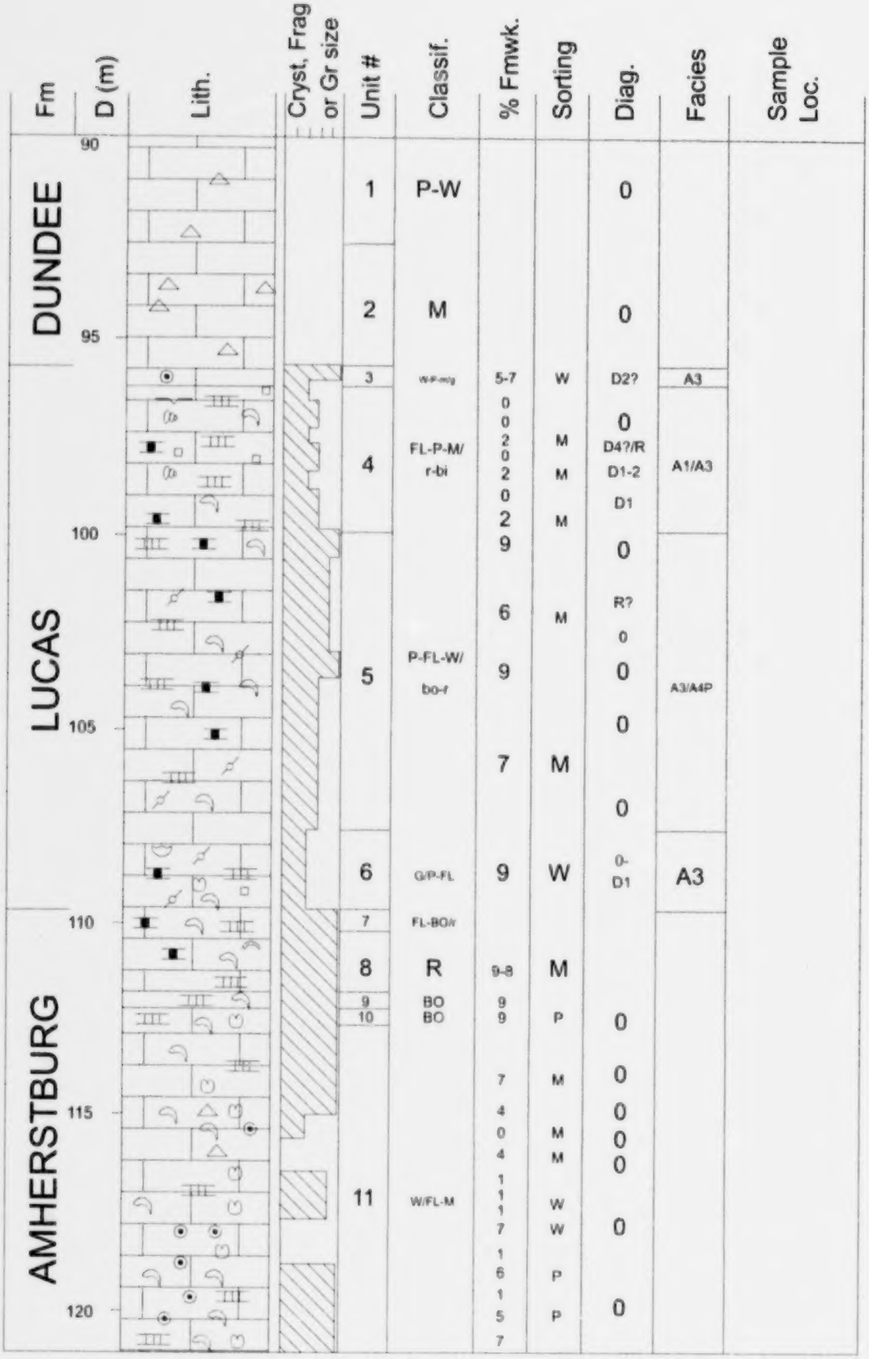
(#51)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
LUCAS
AMHERSTBURG
335
340
345

Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
38	M	1		D8/9 D6 [R] D7/8	M3/M4	
39	M-W	1-3	W	D9 D8 D4/5	M4	LAMB-13
40	G/FL	5/6	M	D4 [R] D9	M3/M4	
41	M-W	1/2 1/2	M M	D5/6	M3	
42	M-W-P	2 0	M-P	D6/7 D9	M4	
43	FL	2-3		D8		
44	R-BO	4 8	P	D4		
45	BO-R	9	P	D1		LAMB-16
46	BO	6	P	D4-7		

Consumers Pan Am 13057
Lake Erie

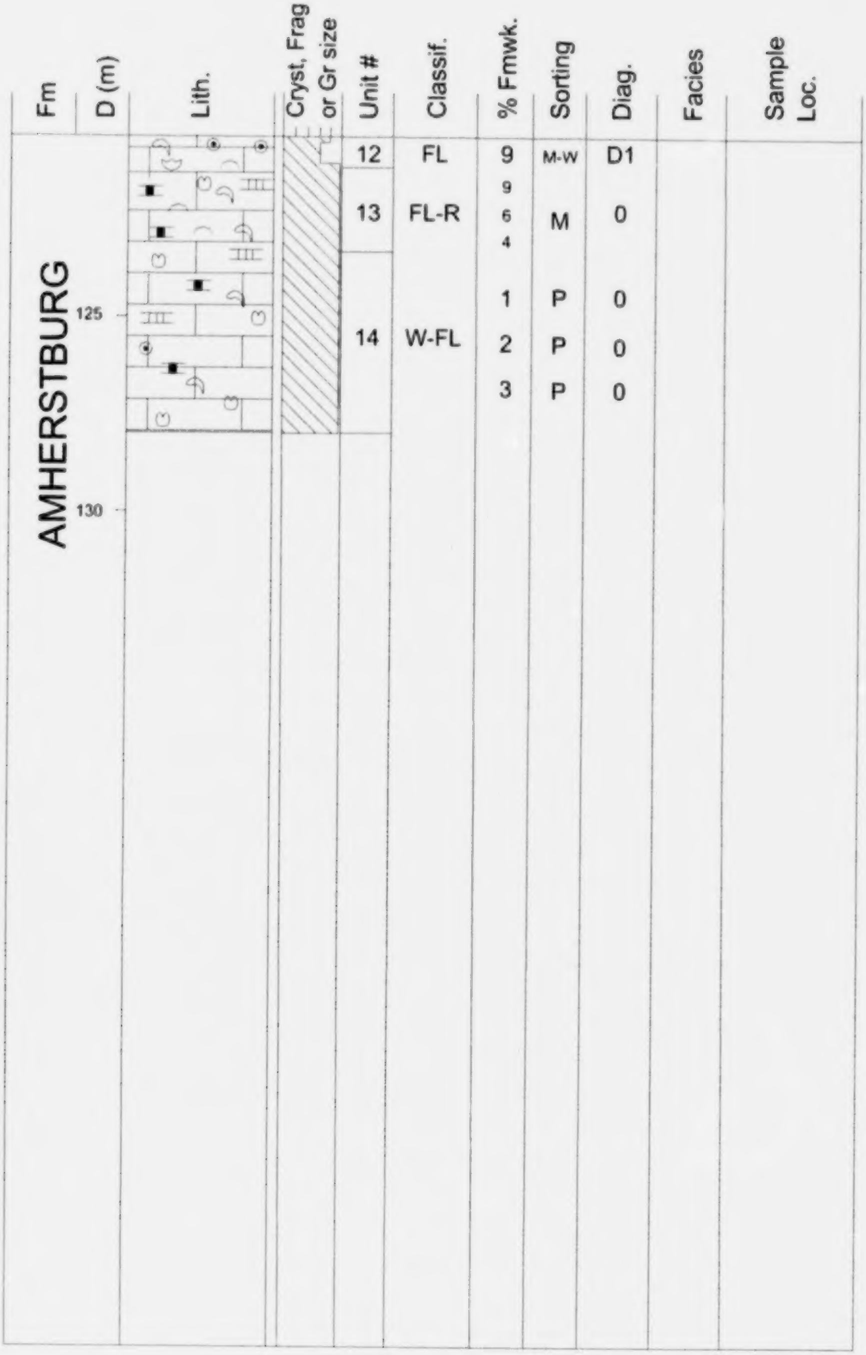
(#71)



Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
AMHERSTBURG
90
95
100
105
110
115
120
1
P-W
0
2
M
0
3
W-P-mg
5-7
W
D2?
A3
4
FL-P-M/
r-bi
0
0
2
0
2
0
2
M
M
M
0
D4?/R
D1-2
D1
A1/A3
5
P-FL-W/
bo-r
9
6
9
7
M
M
0
R?
0
0
0
0
A3/A4P
6
G/P-FL
9
W
0-
D1
A3
7
FL-BO/r
8
R
9-8
M
9
BO
9
10
BO
9
P
0
11
W/FL-M
7
4
0
4
1
1
1
7
1
6
1
5
7
M
M
M
W
W
P
P
0
0
0
0
0
0

Consumers Pan Am 13057
Lake Erie

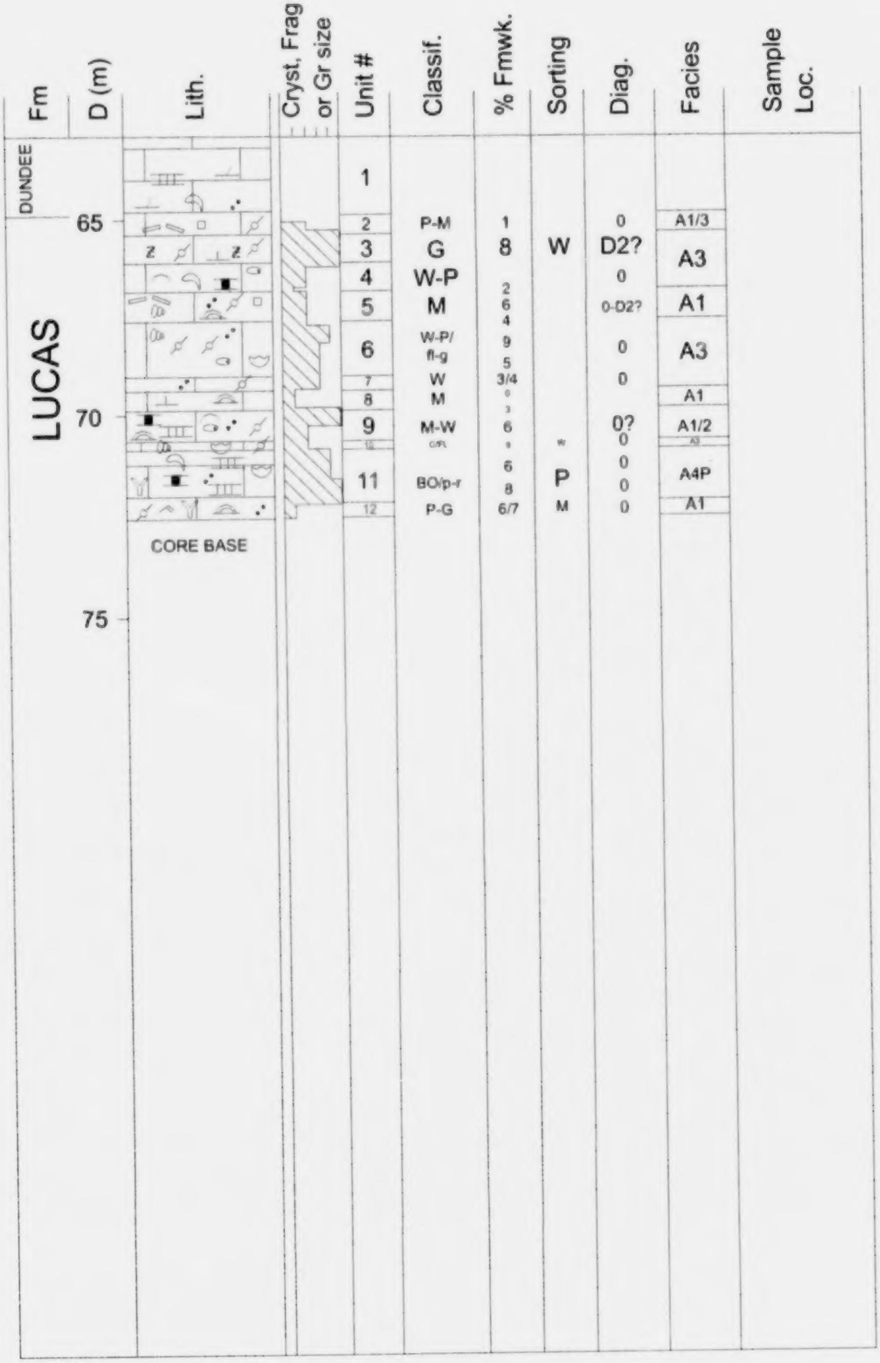
(#71)



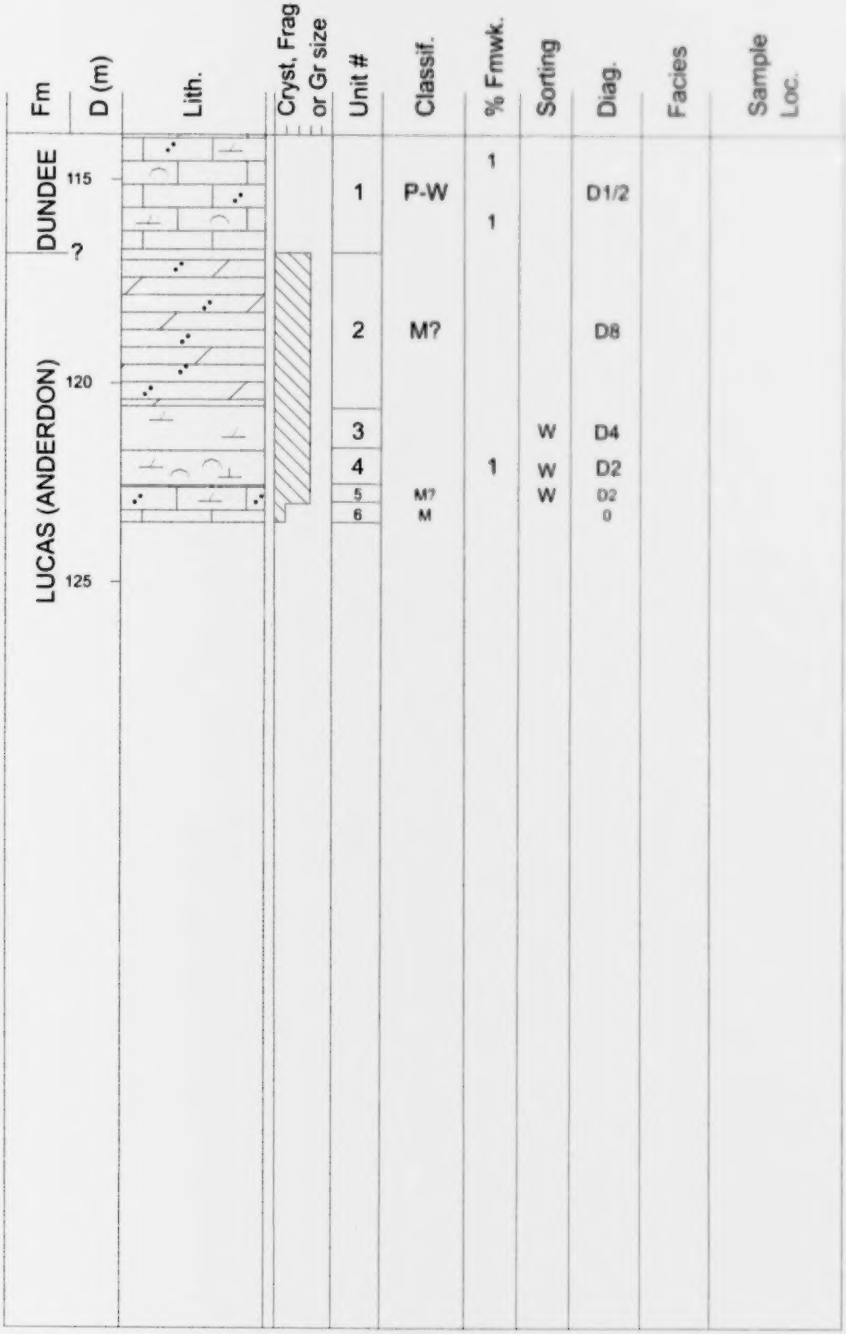
Fm	D (m)	Lith.	Cryst, Frag or Gr size	Unit #	Classif.	% Fmwk.	Sorting	Diag.	Facies	Sample Loc.
AMHERSTBURG				12	FL	9	M-W	D1		
				13	FL-R	9 6 4	M	0		
	125			14	W-FL	1	P	0		
						2	P	0		
						3	P	0		
	130									

Consolidated West Core Test #6
Lake Erie

(#76)

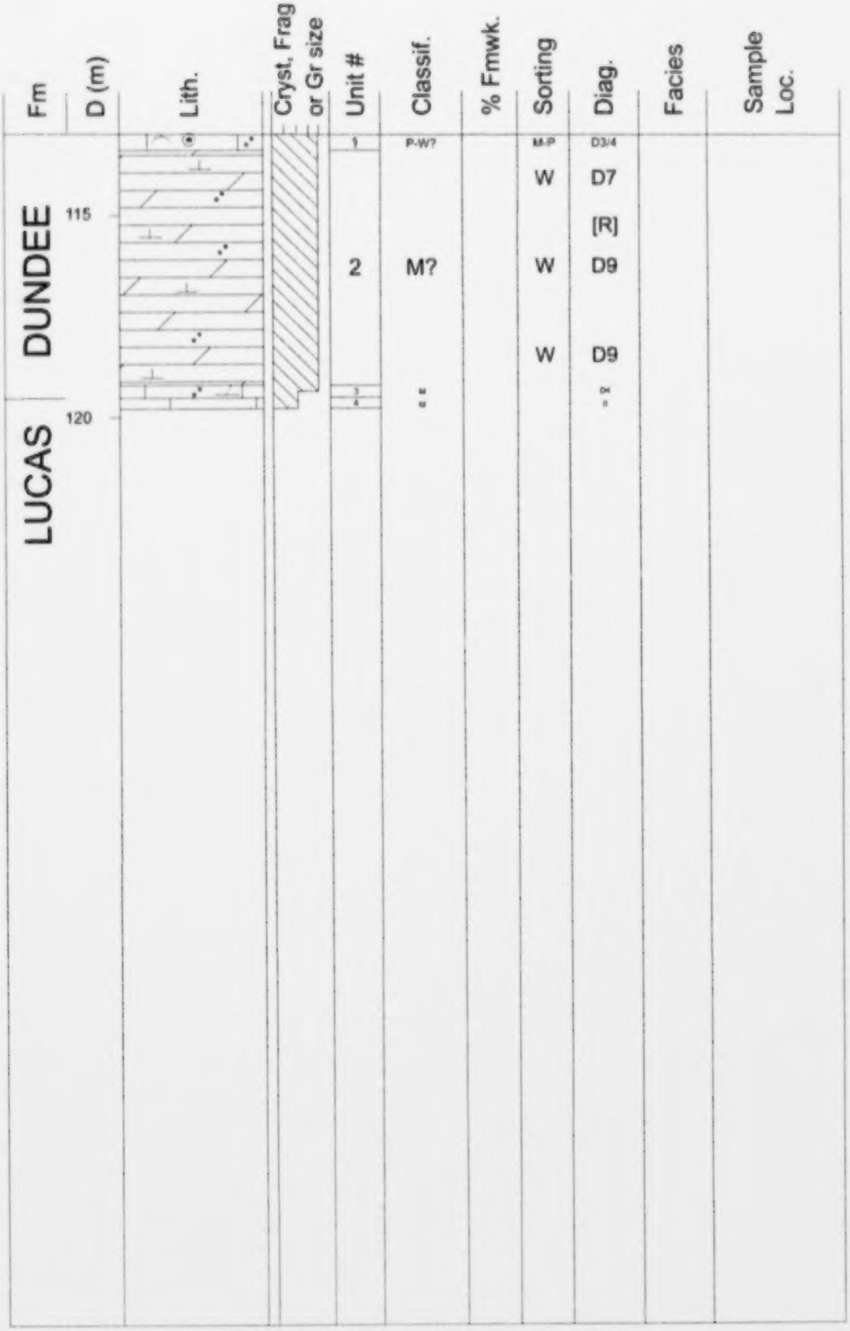


Aldborough Oil and Gas No. 14
Elgin Col, Aldborough Twp.
(Core Chips: ~1m intervals) (#94)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
?
LUCAS (ANDERDON)
115
120
125
1
P-W
1
1
D1/2
2
M?
D8
3
W
D4
4
1
W
D2
5
M?
W
D2
6
M
0

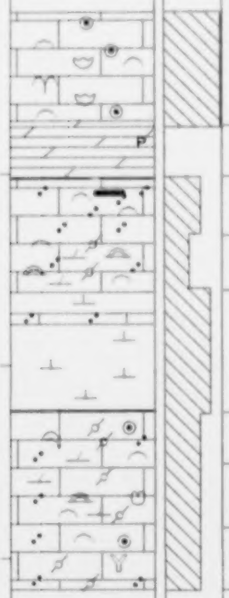
Aldborough Oil and Gas #10
Elgin Co., Aldborough Twp.
(Core chips: 0.3m intervals)

(#122)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
115
120
1
P-W?
M-P
D3/4
W
D7
[R]
2
M?
W
D9
W
D9
3
4

NYK Oil - Monroe No. 1
Lambton Co., Euphemia Twp.
(Core chips: 1.5m intervals)

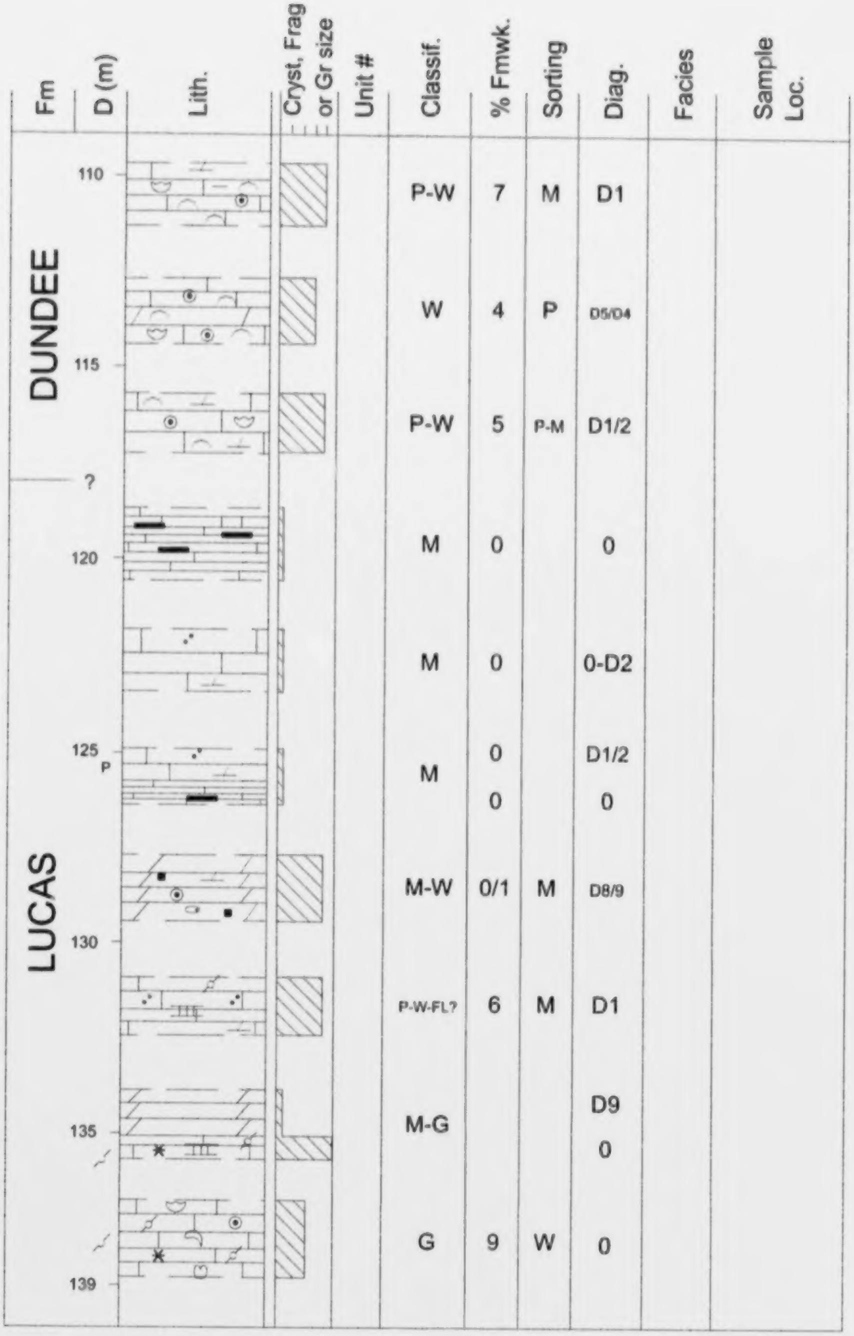
(#143)



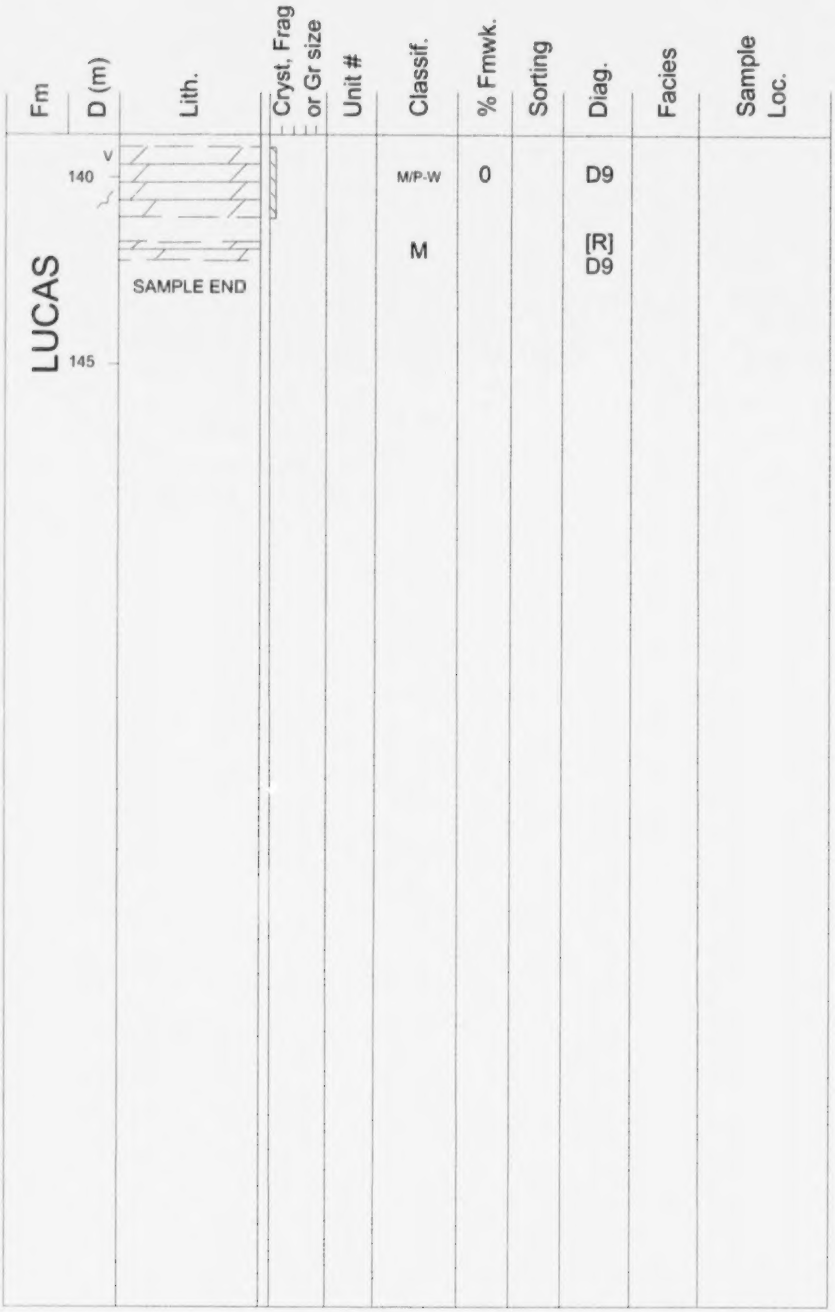
Fm	D (m)	Unit #	Classif.	% Frmwk.	Sorting	Diag.	Facies	Sample Loc.
DUNDEE		1	G-W-P	9 6/7	P P	D0/1 D1/2		
LUCAS (ANDERDON)		2	M	0		D9(R)	A1	
	100	3	G-P	8	M	0	A2	
		4	P	7	M-W	D2/3	A1/A2	
	105	5		1 9 7/8	M P-M	0	A2	
		6	P-G	8/9	M	D1?	A3	
		7	G-P-W	3-8	M	D4/5	A1	
	110	8	G	9	W-M	0	A2/A3	

SAMPLE END

Earl-Bolton No. 1
Middlesex Co., Metcalf Twp.
(Core chips: 3m intervals) (#147)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
DUNDEE
LUCAS
110
115
?
120
125
P
130
135
139
P-W 7 M D1
W 4 P D5/D4
P-W 5 P-M D1/2
M 0 0
M 0 0-D2
M 0 D1/2
0 0
M-W 0/1 M D8/9
P-W-FL? 6 M D1
M-G D9
0
G 9 W 0

Earl-Bolton No. 1
Middlesex Co., Metcalf Twp.
(Core chips: 3m intervals)
Continued (#147)


Fm
D (m)
Lith.
Cryst, Frag or Gr size
Unit #
Classif.
% Fmwk.
Sorting
Diag.
Facies
Sample Loc.
LUCAS
140
145
V
M/P-W
0
D9
M
[R]
D9
SAMPLE END

Appendix E

Litholog Descriptions Listed by County

Appendix E. Litholog descriptions listed by county.

ALDBOROUGH OIL AND GAS NO. 10 **Drill Hole 122**
Elgin Co., Aldborough Tp.; Lot 5, Conc. V **(this study)**
(Tray No. 4521)

*N.B.: Core lost; description based on core chip samples taken at 0.3 m intervals.

Dundee Fm.

113.0 - 113.3m	Unit 1 - tan brown, sparsely sandy, bioclastic (crinoidal debris), dolomitic packstone-wackestone; very fine-grained quartz sand; oil stained.
113.3 - 119.2m	Unit 2 - dark brown-brown, sparsely sandy, nonfossiliferous, medium-crystalline, slightly calcareous dolostone; recrystallized(?). Well-rounded, fine-grained quartz sand; sand content increases upward from <5 to ~20. Possible *Tasmanites*(?) at top. Oil stained.
119.2 - 119.5m	Unit 3 - tan-grey, sandy, nonfossiliferous, dolomitic limestone; fine- to medium-grained quartz sand (~10%).

Lucas Fm.

119.5 - 119.8m	Unit 4 - grey-tan, nonfossiliferous, fenestral micritic mudstone.

—end of core chips—

ALDBOROUGH OIL AND GAS NO. 14 **Drill Hole 94**
Elgin Co., Aldborough Tp.; Lot 4, Conc. V **(this study)**
(Tray No. 5888)

*N.B.: Core lost; description based on core chip samples taken at 1 m intervals.

Dundee Fm.

113.9 - 116.8m	Unit 1 - tan, sandy, dolomitic bioclastic wackestone-packstone (Dundee Facies 1/2); *Tasmanites* present.

Lucas Fm. (Anderdon Member, sandy facies)

116.8 - 120.7m	Unit 2 - dark brown (oil-stained), fine-crystalline dolostone with about 30% fine-grained quartz sand.
120.7 - 121.7m	Unit 3 - dark brown (oil-stained), calcareous, dolomitic sandstone/sandy dolostone; about 50% well-sorted, fine-grained quartz sand.
121.7 - 122.8m	Unit 4 - dark brown (oil-stained), fine-grained, well-sorted, calcareous sandstone with about 10% rounded stromatoporoid, crinoid and echinoderm fragments (2 to 3 mm) in a micritic lime matrix.
122.8 - 123.1m	Unit 5 - sandy dolostone/limestone with about 30% fine-grained, well-sorted quartz grains; <5% crinoid, echinoderm fragments; slightly oil stained.
123.1 - 123.5m	Unit 6 - fenestral(?) micritic limestone.

—end of core chip samples—

CDNOXY RODNEY 5-30

Elgin Co., Aldborough Tp.; Lot 5, Conc. V
(Core # 913)

Drill Hole 27
(this study)

Dundee Fm.

Unit 1 - dolomitic Dundee Facies 1

Lucas Fm.

118.2 - 119.2m Unit 2 - tan to light brown, thinly bedded, fenestral, sparsely fossiliferous, algal-laminated(?), microcrystalline lime mudstone.

119.2 - 120.2m Unit 3 - dark grey, moderately fossiliferous dolomitic wackestone to floatstone; tabulate and rugose corals common in this unit.

Approximately 6 cm of bioturbated calcareous sandstone at base of unit.

* Core may be out of place and basal dolomitic/sandy limestone and dolomite could actually be basal Dundee(?).

—base of core—

CDNOXY RODNEY 6-18

Elgin Co., Aldborough Tp.; Lot 5, Conc. V
(Core #947)

Drill Hole 33
(this study)

Dundee Fm.

114.6 - 118.0m Unit 1 - Dundee Facies 2.

118.0 - 121.0m Unit 2 - dolomitic, crinoidal wackestone to mudstone-floatstone--Dundee Facies 1.

Lucas Fm.

121.0 - 123.8m Unit 3 - dark grey, sparsely to moderately(?) fossiliferous, fine-crystalline, bioturbated, calcareous dolomudstone-dolowackestone(?); occasionally argillaceous; occasional occurrences of laminar stromatoporoids, brachiopods(?), leached *Amphipora*, and thin (4 to 6 cm), oil-stained intervals of argillaceous dolorudstone-dolofloatstone(?). Very porous (intercrystalline, vuggy, moldic); dolomitization has obliterated most features; <5% fine quartz sand.

—base of core—

OGS-82-3
Elgin Co., Yarmouth Tp.; Lot 9, Conc. I
(Core #861)

Drill Hole 26
(this study)

Dundee Fm.

Dundee Facies 3

Lucas Fm.

132.4 - 140.4m Unit 1 - tan to light grey, fenestral micritic limestone beds interbedded with moderately fossiliferous stromatoporoid-coral boundstones and floatstones. Thin graded beds with sorted bioclastics (<0.5 cm diameter) grading up to fenestral micritic beds. Occasional thamnoporid fragments.

Sandy bed ~10 cm thick at 136 to 136.3m. Pyrite mineralization at 132.9 m.

140.4 - 144.0m Unit 2 - brown, medium-bedded, sparsely to moderately fossiliferous mudstone-wackestone-boundstone with thin tabular stromatoporoids, trilobites and rugose coral fragments; wispy argillaceous seams. Crinoids ~10 to 20%. Thin, 1 cm long mudstone intraclasts at 142.2 m.

144.0 - 146.8m Unit 3 - tan to brown, fenestral micritic mudstone; occasional *Amphipora* pulses (rudstone ~5 cm thick); common fine peloids. Occasional gastropods and brachiopods(?).

146.8 - 151.5m Unit 4 - tan, buff to light grey, fossiliferous grainstone-rudstone-floatstone with about 40% coarse grain-supported rudstone pulses set in a tan, fine-grained grainstone to floatstone matrix. Small thamnoporids, rounded stromatoporoids (~2 cm diameter) and thamnoporid fragments common. Uncommon thin tabular stromatoporoids. Gastropods very common. At 151.5 to 152.0 m -tan grainstone, no coarse fossils.

(Backreef-lagoonal/storm deposits)

Amherstburg Fm.

152.0 - 154.0m Unit 5 - about 1.5 m of <1 cm diameter *Amphipora*, thamnoporid, colonial rugose coral fragment rudstones. Occasional thin tabular stromatoporoids.

(Backreef/flat facies)

154.0 - 160.0m Unit 6 - BUILDUP PHASE: ↑ tabular to massive and domal stromatoporoids; common large rugose coral and coarse thamnoporid sticks. Boundstones with ~10 to 20 cm diameter stromatoporoids at top.

(Reef facies)

160.0 - 163.0m Unit 7 - tabular stromatoporoids very common (50 to 70%); thamnoporid corals also common. *Amphipora* less common to uncommon.

163.0 - 173.0m Unit 8 - grey to dark brown, fossiliferous limestone; dominantly fine *Amphipora* sticks, large rugose and fine branching tabulate corals common; about 5 to 10% dark grey to tan chert nodules. Stromatoporoid-coral rudstone pulses in dark brown wackestone matrix. Colonial rugose uncommon. Crinoids (~10 to 15%) common between 163.5 to 165.0 m. Fenestrate bryozoans uncommon between ~164 and 165 m. Uncommon <1 cm diameter thamnoporid corals.

Dark brown-black thin carbonaceous seams common in mudstone-wackestone intervals (lower framework %). Decreasing abundance of *Amphipora* upwards.

Bois Blanc Fm.

173.0 - 178.0m Unit 9 - grey to brown cherty limestone; about 30 to 40% grey-white chert nodules; crinoids, rugose and tabulate corals common; laminar stromatoporoids, brachiopods also common. 5 to 10 cm crinoidal bioclastic pulses (rudstones) uncommon.

LUCAS NO. 3
Essex Co., Anderdon Tp.; Lot 4 Conc. VIII
(Core #881)

Drill Hole 2
(this study)

Dundee Fm.

7.0 - 21.4m	Unit 1 - tan to brown, moderately fossiliferous, slightly dolomitic lime wackestone-packstone facies. Thin fossiliferous packstone pulses, <30 cm thick, uncommon in lower few metres becoming more common upward, making up to about 20% of lithology. Bryozoans, brachiopods, crinoids, rugose corals most common fossils. Chert rare to absent above ~16 m; common below, comprising about 10 to 15%.
	"Bioclastic limestone."
	Coarse leached fractures between 19 and 21 m.
21.4 - 24.3m	Unit 2 - sparsely sandy, wispy dolomudstone with white chalky chert nodules; bioturbated; *Tasmanites*/*Tentaculites* common.

Lucas Fm. (Anderdon Mb.)

24.3 - 26.6m	Unit 3 - light grey to tan, sandy mudstone and sandy dolomitic mudstone beds; thinly bedded to laminated; occasional mudstone rip-ups and tepee structures (dewatering).
26.6 - 27.2m	Unit 4 - light tan to cream-coloured, massive to faintly cross-laminated calcareous sand-stone to sandy limestone.
27.2 - 27.8m	Unit 5 - tan pelletal grainstone (*Leiosphaerids*)
27.8 - 29.3m	Unit 6 - light grey to tan, sandy, grey-mottled, massive- to medium-bedded dolomudstone-floatstone; rare leached thamnoporid/*Amphipora* sticks; pulses of pelleted(?)/algal grainstone (*Leiosphaerids*).
	* Basal massive, mottled, stylolitized finely crystalline dolomitic mudstone is similar to unit in MacGregor quarry, Amherstburg, Ontario.

LUCAS NO. 2
Essex Co., Colchester South Tp.; Lot 11, Conc. V
(Core #882)

Drill Hole 3
(this study)

Dundee Fm.

15.0 - 23.2m	Unit 1 - pseudonodular bioclastic wackestone. Sparsely fossiliferous; common burrows (mining structures). Uncommon crinoids, brachiopods, bryozoans, rugose corals. Stylolitic.
23.2 - 24.5m	Unit 2 - crinoidal grainstone-packstone.
24.5 - 26.8m	Unit 3 - sandy, crinoidal dolowackestone; very fine- to fine-grained, well rounded quartz sands, with decreasing sand upward, and increasing fossiliferous materials, especially crinoids, solitary rugose corals and brachiopods.

Lucas Fm. (Anderdon Mb.?)

26.8 - 27.7m	Unit 4 - *Aulopora*-tabular stromatoporoid bafflestone-boundstone-floatstone in a brown, carbonaceous, fine-crystalline mudstone matrix.
27.7 - 28.7m	Unit 5 - dark to light brown, laminated mudstone-wackestone; occasional thin, laterally discontinuous laminar stromatoporoids. Stromatoporoid-encrusted corals.
28.7 - 29.6m	Unit 6 - tan to brown, laminar to tabular stromatoporoid boundstone with dark brown argillaceous and carbonaceous seams; tubular *Aulopora* common; uncommon small thamnoporid branches.
	*Lower 3 m of core similar to uppermost stromatoporoid-coral biostrome at the Amherst quarry, Amherstburg, Ontario.

IMPERIAL ET AL. 813, REIMER #1
Essex Co., Gosfield South Tp.; Lot 6, Conc. IV
(Core #197)

Drill Hole 4
(this study)

Lucas Fm.

41.0 - 42.2m	Unit 1 - tan to grey, algal laminated micro-to very fine-crystalline dolomudstone. Sparse subangular to subrounded, very fine sand grains.
42.2 - 43.2m	Unit 2 - thin- to medium-bedded, argillaceous, sparsely fossiliferous mudstone-wackestone with common gastropods.
43.2 - 43.8	Unit 3 - coarse pelletal grainstone grading upward to pellet-gastropod wackestone and capped by grey-brown, dolomitic, gastropod-rich packstone.
43.8 - 44.3m	Unit 4 - laminated dolomudstone.
44.3 - 49.1m	Unit 5 - massive, tan, finely crystalline, wispy argillaceous dolomitic mudstone-wackestone with peloids and thamnoporid fragments grading up to brown to dark brown fenestral, thin-bedded mudstone and tan-brown, argillaceous dolomitic wackestone with argillaceous seams. Rare domal stromatoporoid and colonial rugose corals in upper part of unit; common ostracods.
49.1 - 49.3m	Unit 6 - porous, vuggy, massive, homogeneous, tan to light grey dolomudstone; moldic porosity; thamnoporid branches.
49.3 - 50.8m	Unit 7 - tan-grey laminated dolomudstone.
50.8 - 51.4m	Unit 8 - porous, vuggy-moldic porosity, light grey dolomudstone; common leached thamnoporids.
51.4 - 53.8m	Unit 9 - tan to light grey to light brown, thinly bedded, laminated to algal-laminated dolomudstone; very fine crystalline; common dark carbonaceous seams.
53.8 - 55.8m	Unit 10 - light grey to tan, thinly bedded, peloidal dolomudstone-dolopackstone; moldic pellet porosity common.
55.8 - 58.3m	Unit 11 - tan to light brown to grey, thin-bedded to laminated, very fine- to fine-crystalline dolomudstone with dark carbonaceous laminae.
58.3 - 59.1m	Unit 12 - porous (vuggy-moldic porosity), massive, light grey dolomudstone; leached thamnoporids.
59.1 - 60.8m	Unit 13 - tan-light brown, very porous, massive- to faintly laminated dolomudstone grading up to wispy, argillaceous dolomudstone-wackestone with occasional thamnoporid fragments.

Amherstburg Fm.

60.8 - 62.3m	Unit 14 - brown to dark brown dolomudstone with uncommon small tabulate corals.
62.3 - 65.8m	Unit 15 - dark brown, moderately fossiliferous, coralliferous lime wackestone-floatstone; uncommon crinoids, common domal tabulates, fasciculate stromatoporoids and colonial rugose coral branches. Uncommon thin tabular stromatoporoids. Rare chert.
65.8 - 67.0m	Unit 16 - tabular stromatoporoid/*Amphipora*/coral reef facies.

LUCAS NO. 1 — **Drill Hole 16**
Essex Co. Mersea Tp.; Lot 6, Conc. IV — **(this study)**
(Core #883)

Dundee Fm.

20.0 - 22.6m	Unit 1 - medium-bedded, brown crinoid-brachiopod wackestone.
22.6 - 24.1m	Unit 2 - moderately fossiliferous wackestone interbedded with packstone-rudstone pulses; coarse pulses indurated and slightly pyritized.
24.1 - 25.8m	Unit 3 - crinoid-brachiopod wackestone; no charophytes.
25.8 - 29.9m	Unit 4 - cherty, dolomitic wackestone with similar fossil constituents as below. Hydrocarbon staining.
29.9 - 32.1m	Unit 5 - light brown, slightly argillaceous, sparsely fossiliferous dolomitic mudstone-wackestone; uncommon bryozoans, crinoids, charophytes, brachiopods, *Tasmanites*. Very fine intercrystalline porosity.

CANSALT DDH 87-3 — **Drill Hole 1**
Essex Co., Sandwich West. Tp.; Fighting Island — **(this study)**
(Core #953)

Lucas Fm.

32.0 - 32.4m	Unit 1 - algal/peloidal grainstone.
32.4 - 35.3m	Unit 2 - tan, massive, peloidal to algal-laminated dolomudstone (compare below). Vuggy porosity with calcite infill.
35.3 - 38.8m	Unit 3 - tan, massive, peloidal, wispy to thin algal-laminated dolomudstone. Good intraparticle porosity. About 20 to 60 cm thick algal (*Leiosphaerids*)/peloidal grainstone beds.
38.8 - 39.8m	Unit 4 - tan to brown, sparsely fossiliferous, burrow-mottled mudstone, uncommon ostracods.
39.8 - 45.7m	Unit 5 - tan-light brown-grey algal-laminated dolomudstone with common celestite replacement in lower 30 cm. Uppermost ~50 cm possibly peloidal or algal(?) (*Leiosphaerids*). Thin black clay seam/breccia at ~44.6 m.
45.7 - 50.7m	Unit 6 - tan to buff, thin-bedded, algal-laminated dolomitic mudstone with carbonaceous seams; small celestite nodules.

Amherstburg Fm.

50.7 - 50.8m	Unit 7 - grey-light grey-tan, mottled dolomitic mudstone; exposure surface with phosphatics(?); sandy.
50.8 - 51.8m	Unit 8 - tan to brown, moderately fossiliferous wackestone-floatstone with occasional crinoids, colonial rugose branches and uncommon thin tabulate corals. Rare small domal tabulates (*Favosites*) and common *Amphipora*. Uncommon *Aulopora*.
51.8 - 52.3	Unit 9 - brown fossiliferous rudstone, Amphipora, tabular stromatoporoids, thin thamnoporids and Aulopora common. Intraskeletal porosity.
52.3 - 54.7m	Unit 10 - brown-dark brown-black tabular stromatoporoid boundstone with occasional *Aulopora*, coarse thamnoporid branches and *Amphipora*. Very fine-grained mudstone-wackestone matrix; slightly dolomitized. Carbonaceous.
54.7 - 56.3m	Unit 11 - brown-dark brown thamnoporid floatstone to tabular stromatoporoid boundstone.
56.3 - 58.4m	Unit 12 - brown stromatoporoid rudstone-bindstone-framestone with basal fine *Amphipora* rudstone grading up to tabular stromatoporoid bindstone-floatstone-framestone. Upper 1 m has common 3 to 5 cm diameter, well-rounded domal stromatoporoids. Carbonaceous. Oil show. Massive ~10 to 20 cm diameter stromatoporoids in framestone. Dolomitic mudstone-wackestone matrix. Intercrystalline and intraskeletal porosity.
58.4 - 62.0m	Unit 13 - brown-dark brown, wispy dolomitic mudstone-wackestone with uncommon thamnoporids, small tabular corals, and tabular stromatoporoids.

DOMTAR TEST #3
Huron Co., Goderich Tp.
(Core #764)

Drill Hole 17
(this study)

**N.B. Incomplete core recovery. A total of 28.7 m of core missing throughout cored interval.

Lucas Fm.

14.2 - 18.8m	Unit 1 - tan, thinly laminated dolomudstone with thin carbonaceous seams.
18.8 - 19.5m	Unit 2 - tan-buff to cream, very soft caliche(?).
19.5 - 21.0m	Unit 3 - dark brown calcareous mudstone with angular dolomudstone clasts.
21.0 - 24.4m	Unit 4 - thin-laminated dolomudstone with moldic lath porosity (calcite replacement); carbonaceous seams.
24.4 - 24.8m	Unit 5 - dark brown, vuggy calcareous mudstone.
24.8 - 26.3m	Unit 6 - tan, thinly laminated to massive dolomudstone with moldic lath porosity.
26.3 - 27.1m	Unit 7 - Sandy, stromatolitic calcareous boundstone; <1 cm thick laminae of well sorted, subrounded quartz grains (very fine- to fine-grained); angular stromatoporoid clasts.
27.1 - 28.6m	Unit 8 - tan, thin-laminated to massive dolomudstone.
28.6 - 31.2m	Unit 9 - brown to dark grey, thinly laminated, porous dolomudstone. Coarse pebble to cobble-sized, angular dolomudstone clasts in a dark grey lime mudstone matrix. (Channel?) Tan-brown, massive dolomudstone with stromatolites immediately underlying breccia.
31.2 - 34.5m	Unit 10 - tan, massive dolomitic mudstone with common small evaporite laths.
34.5 - 36.3m	Unit 11 - dark grey calcareous mud/clay (nonmarine?) Vuggy porosity (anhydrite lath dissolution vugs). Tan to grey mottled dolomudstone. Breccia(?); dark grey calcareous mudstone.
36.3 - 44.0m	Unit 12 - tan, massive to brown-buff, laminated and grey, massive to laminated dolomudstone.
44.0 - 45.9m	Unit 13 - massive dolomudstone-floatstone grading to massive, wispy, dark brown dolomudstone.
45.9 - 50.2m	Unit 14 - tan to buff, massive, wispy argillaceous dolomudstone grading up into massive, vuggy, moderately fossiliferous, tan dolowackestone-floatstone with brachiopods and thamnoporid/colonial rugose coral fragments (secondary dolomite)
50.2 - 53.3m	Unit 15 - tan to buff, massive to laminated dolomudstone.
53.3 - 56.6m	Unit 16 - tan-light brown, laminated dolo-mudstone (primary) with intraformational breccia. Breccia consists of tan, dolomitic clasts leached out of a grey-brown mudstone matrix. Dark grey, thinly laminated dolomudstone (petroliferous) at top.
56.6 - 60.1m	Unit 17 - coral-stromatoporoid, dolomitic boundstone-floatstone grading upward to laminated dolomudstone. (All secondary dolomite).
60.1 - 64.8m	Unit 18 - laminated dolomudstone grading upward to massive, stromatoporoid-coral dolofloatstone. Small colonial rugose branches common at top.
64.8 - 70.0m	Unit 19 - tan to light brown-buff to light grey, thinly laminated dolomudstone with coarse intraformational breccias (channel cuts). Grades upward to medium-bedded, grey dolomudstone. Anhydrite laths (<5 mm) common → dissolved molds! Solution collapse(?) features at base.

BRETT **Drill Hole 38**
Kent Co., Camden Gore Tp.; Lot 5, Conc. XIV **(this study)**
(Core #887)

Lucas Fm.

	*Lucas here is porous and oil stained, possibly affecting dolomite determinations; many features have been obliterated/altered by recrystallization.
178.9 - 179.9m	Unit 1 - brown-grey, moderately to nonbioturbated, nonfossiliferous(?), algal(?) dolomudstone. Near top, 26 cm thick interval of *Amphipora*-brachiopod-rugose coral floatstone; minor thin laminar stromatoporoids(?).
179.9 - 180.4m	Unit 2 - brown, bioturbated(?) *Amphipora* floatstone set in a dolomicritic/dolomudstone matrix; occasional laminar-tabular stromatoporoid intervals and *Amphipora* rudstone pulses. Frequent carbonaceous seams.
180.4 - 181.1m	Unit 3 - tan, vuggy, massive, nonfossiliferous dolomicrite.
181.1 - 184.2m	Unit 4 - dark brown, irregularly laminated, laminar stromatoporoid dolomudstone-dolowackestone-doloboundstone(?)-dolofloatstone with dendritic and *Amphipora* stromatoporoids and minor rugose corals and echinoderm fragments; 20 to 30 cm thick *Amphipora*-thamnoporid dolofloatstone-rudstone (dolomudstone matrix) pulses at top and at 182.5 m. Patchy dolomitization; fossils calcareous. Frequent carbonaceous seams.
184.1 - 184.5m	Unit 5 - brown fine-crystalline dolomudstone; occasional thamnoporid corals and carbonaceous seams.
184.5 - 185.0m	Unit 6 - tan-brown laminar stromatoporoid-*Amphipora*-rugose coral doloboundstone set in dolomudstone matrix.
	—base of core—

OGS-82-2
Kent Co., Harwich Tp.; Lot 25, Conc. IECR
(Core #860)

Drill Hole 8
(this study)

Dundee Fm.

150.0 - 151.4m	Unit 1 - Dundee Facies 2.

Lucas Fm. (Anderdon Mb. equivalent(?) - 151.4 to 158.2 m)

151.4 - 153.9m	Unit 2 - tan to light brown, carbonaceous, slightly dolomitic, laminated, fenestral mudstone with common peloidal grainstone pulses. Occasional thin, dark brown-black organic layers (nonmarine exposure?).
153.9 - 155.0m	Unit 3 - buff to brown, medium-bedded, moderately fossiliferous stromatoporoid-coral floatstone-wackestone; occasional colonial rugose coral fragments, thin laminar stromatoporoids, and *Amphipora*.
155.0 - 155.9m	Unit 4 - dolomitic *Amphipora* floatstone-rudstone; intercrystalline porosity.
155.9 - 158.2m	Unit 5 - tan-buff-light brown, medium-bedded peloidal grainstone-mudstone to stromatoporoid-coral floatstone.
158.2 - 158.6m	Unit 6 - tan-brown, laminar to tabular stromatoporoid bindstone; rare *Amphipora*.
158.6 - 163.8m	Unit 7 - tan to light brown to light grey, thinly laminated mudstone with sparse small rugose coral fragments; microstylolites and thin carbonaceous seams.
163.8 - 165.0m	Unit 8 - *Amphipora* rudstone, fasciculate to tabular stromatoporoid floatstone.
165.0 - 166.7m	Unit 9 - peloidal packstone-grainstone with common subangular to subrounded quartz grains; low-angle cross-bedding.
166.7 - 170.6m	Unit 10 - grey to brown, micritic lime mudstone; thin- to medium-bedded with coarse secondary anhydrite/celestite(?) replacement. Large sulphate nodules (up to about 10 cm diameter). Sulphate-filled fractures.
170.6 - 171.3m	Unit 11 - intraformational breccia with sparse angular quartz grains.
171.3 - 172.8m	Unit 12 - tan to grey, massive- to thin-bedded, micritic limestone; about 5 to 10% brown anyhdrite laths/mottles. Fractures filled with anhydrite.
172.8 - 173.8m	Unit 13 - brown, massive peloidal packstone-grainstone with occasional stromatoporoid fragments and small domal stromatoporoids; secondary anhydrite replacement (<10%).
173.8 - 180.0m	Unit 14 - tan to light grey, thinly laminated mudstone facies; occasional microstylolites in more argillaceous mudstone.
180.0 - 181.0m	Unit 15 - light grey to brown peloidal mudstone-packstone; uncommon corals.
181.0 - 184.1m	Unit 16 - irregular stromatoporoid-*Amphipora*-thamnoporid coral floatstone-wackestone.
184.1 - 184.5m	Unit 17 - irregular stromatoporoid-*Amphipora* rudstone to floatstone.

Amherstburg Fm.

184.5 - 190.3m	Unit 18 - tan to brown to light grey stromatoporoid bindstone-framestone. Irregular and tabular stromatoporoids very common to abundant; thamnoporid corals, small domal tabulates uncommon. (Reef facies.) Unit becomes increasingly carbonaceous towards top, with thin dark brown to black mudstone seams. Tightly cemented (anhydrite), with some intraskeletal porosity.
190.3 - 191.5m	Unit 19 - brown, sparsely fossiliferous mudstone to wackestone; rare chert; crinoids, corals (thamnoporids) and thin tabular stromatoporoids uncommon.
191.5 - 192.1m	Unit 20 - brown, moderately fossiliferous stromatoporoid-crinoid-coral bindstone to floatstone.
192.1 -195.0m	Unit 21 - tan to light brown, massive, cherty mudstone with wispy seams.
195.0 - 200.7m	Unit 22 - brown, slightly cherty (<10%), fossiliferous mudstone-wackestone-floatstone facies with common irregular stromatoporoid-colonial rugose coral branch pulses and crinoid fragments. Abundant dark brown mud lenses, about 2 to 5 mm long and 1 to 2 mm wide.
200.7 - 204.0m	Unit 23 - coarse crinoid-coral rudstone-floatstone-bafflestone with about 20%+ chert; large tabulate corals common with very coarse crinoidal fragments. Occasional anhydrite nodules.

CONSUMERS 33408A
Kent Co., Tilbury East Tp.; Lot 2, Conc. X
(Core #772)

Drill Hole 7
(this study)

Dundee Fm.

125.0 - 126.7m	Unit 1 - massive, dark grey, medium-crystalline dolostone; common (~15%) fine-grained quartz sands.

Lucas Fm.

126.7 - 128.6m	Unit 2 - dark brown-bluish stromatolite mound with dark laminae; bluish anhydrite nodules common (probably out of place!).
128.6 - 131.5m	Unit 3 - brown to tan, moderately fossiliferous packstone-grainstone interbedded with thinly laminated carbonaceous mudstones and thin stromatoporoid-coral bindstone-bafflestone pulses in a wackestone-packstone matrix. Sparse subrounded quartz grains. Common to abundant small turbinate gastropods at top of unit.
131.5 - 132.8m	Unit 4 - stromatoporoid bindstone-framestone(?) with tabular and large domal stromatoporoids (up to ~20 cm diameter) uncommon in a sparsely fossiliferous mudstone-wackestone matrix.
132.8 - 135.9m	Unit 5 - laminated mudstone with thin *Amphipora*-coral pulses rarely occurring.
135.9 - 136.8m	Unit 6 - sandy *Amphipora*, tabular stromatoporoid, coral fragment rip-ups/packstone-grainstone. (Reworked!) About 10 to 15% very fine- to fine-grained, subangular to subrounded quartz sands.
136.8 - 138.1m	Unit 7 - light grey to light brown, massive peloidal packstone-grainstone. Planar laminated, low-angle to small-scale cross-bedded; poor intergranular porosity.
138.1 - 140.0m	Unit 8 - same as immediately below with abundant *Amphipora*; *Amphipora* very coarse at top, with colonial rugose fragments and *Aulopora* also present. Distorted laminae in upper 1 m.
140.0 - 145.9m	Unit 9 - tan to light brown, moderately fossiliferous mudstone-floatstone pulses set in a mudstone-wackestone matrix interbedded with thinly bedded to thinly laminated algal mudstone. Same fauna as below.
	*Deeper water than typical laminated Lucas facies.
145.9 - 148.4m	Unit 10 - tan to light grey, thinly laminated algal mudstone.
148.4 - 150.2m	Unit 11 - tan to cream peloidal grainstone to packstone.
150.2 - 152.8m	Unit 12 - tan to light brown, algal-laminated mudstone with occasional thin. moderately fossiliferous floatstone pulses; large *Amphipora*, colonial rugose coral, and brachiopod fragments.

Amherstburg Fm.

152.8 - 155.7m	Unit 13 - brown, *Amphipora*-thamnoporid-thin laminar to tabular stromatoporoid boundstone to floatstone set in a muddy wackestone matrix. Occasional stromatoporoid-encrusted colonial rugose fragments.
155.7 - 159.3m	Unit 14 - tabular stromatoporoid boundstone with ~20 cm interbeds of dark brown-black, carbonaceous stromatoporoid-coral boundstone to floatstone. Irregular and thick tabular stromatoporoids very common.
159.3 - 162.2m	Unit 15 - brown, moderately fossiliferous, thin laminar stromatoporoid-coral floatstone to bafflestone with a mudstone-wackestone matrix. Fasciculate tabulates and small thamnoporids common; crinoid fragments.
162.2 - 163.0m	Unit 16 - tan to light brown to light grey, tabular stromatoporoid boundstone with small fasciculate tabulate coral colonies.

CONSUMERS 33409
Kent Co., Tilbury E. Tp.; Lot 4, Conc. IX
(Core #751)

Drill Hole 6
(this study)

* See Consumers 33408A core (#772) Kent Co., Tilbury E. Tp., for detailed lithologic descriptions.

Dundee Fm.	
120.0 - 120.6	sandy, medium-crystalline dolostone.
Lucas Fm.	
120.60 - 124.4m	Unit 1 - stromatoporoid-coral wackestone with massive peloidal packstone-grainstone pulses; common small gastropods at top of unit.
124.4 - 125.1m	Unit 2 - stromatoporoid boundstone.
125.1 - 126.1m	Unit 3 - massive mudstone.
126.1 - 126.8m	Unit 4 - tabular to massive stromatoporoid bindstone-bafflestone.
126.8 - 129.3m	Unit 5 - massive, sandy lime mudstone-wackestone.
129.3 - 131.4m	Unit 6 - peloidal packstone-grainstone facies.
131.4 - 132.8m	Unit 7 - stromatoporoid-coral-*Amphipora* floatstone interbedded with massive and laminated mudstone.
132.8 - 133.2m	Unit 8 - robust thamnoporid-colonial rugose coral branch floatstone.
133.2 - 134.9m	Unit 9 - *Amphipora*-stromatoporoid floatstones/boundstones with occasional *Aulopora*.
134.9 - 135.3m	Unit 10 - laminated mudstone facies.
135.3 - 138.6m	Unit 11 - tabular stromatoporoid bindstone, stromatoporoid-colonial rugose coral bafflestone, coral-stromatoporoid wackestones in a mudstone-wackestone matrix.
138.6 - 141.0m	Unit 12 - laminated mudstone facies.
141.0 - 146.0m	Unit 13 - tabular stromatoporoid-*Amphipora* floatstones interbedded with massive wackestones and thinly bedded to laminated mudstones.
Amherstburg Fm.	
146.0 - 148.2m	Unit 14 - *Amphipora*-irregular stromatoporoid-thamnoporid backreef/reef cap facies.
148.2 - 150.0m	Unit 15 - tabular stromatoporoid reef facies.

CONSUMERS AMOCO 13076
Lake Erie 51 - A
(Core #957)

Drill Hole18
(this study)

Dundee Fm.

96.5 - 97.0m	Unit 1 - Dundee Facies 2.
97.0 - 97.5m	Unit 2 - dark brown, thin-bedded micritic mudstone (Facies 3).
97.5 - 98.4m	Unit 3 - Dundee Facies 2.
98.4 - 98.8m	Unit 4 - calcareous sandstone.
98.8 - 99.4m	Unit 5 - dolomitized, sparsely sandy Facies 2.

Lucas Fm. (Anderdon Mb.)

99.4 - 99.6m	Unit 6 - peloidal, gastropod-rich grainstone; common small *Amphipora*.
99.6 - 101.4m	Unit 7 - brown, massive, peloidal grainstone to dark brown micritic mudstone with black carbonaceous seams. Peloids <177 microns.
101.4 - 102.2m	Unit 8 - brown, slightly carbonaceous stromatoporoid-coral boundstone to mudstone. Common irregular stromatoporoids. *Amphipora* and thamnoporids.
102.2 - 102.5m	Unit 9 - massive peloidal grainstone.
102.5 - 106.1m	Unit 10 - massive, grey-brown, sandy, fenestral peloidal grainstone (faecal pellets!). Massive, brown, micritic to peloidal mudstones; light brown, laminated peloidal mudstones are fenestral. Uncommon thin black carbonaceous seams. Uncommon large (~40 cm diameter) domal stromatoporoids flanked by thin *Amphipora* pulses. Sparsely sandy (subrounded, grey, black, and clear quartz grains).
106.1 - 106.2m	Unit 11 - sandy limestone on erosive contact.
106.2 - 120.4m	Unit 12 - massive, light brown to brown micritic mudstone to fine peloidal mudstone. Frequent 5 to 30 cm thick stromatoporoid-coral pulses with *Amphipora*, irregular stromatoporoids and stromatoporoid-encrusted colonial rugose corals. Rare thamnoporids. Peloidal mudstones are fenestral. Possibly cyclic: basal stromatoporoid, fossiliferous pulse to micritic mudstone and capped by peloidal mudstone(?).

Amherstburg Fm.

120.4 - 121.8m	Unit 13 - *Amphipora*-rich floatstone.
121.8 - 125.0m	Unit 14 - irregular, laminar and tabular stromatoporoid reef facies. Dark brown to black; very carbonaceous.

CONSUMERS PAN AM 13057
Lake Erie 56 - E
(Core #999)

Drill Hole 71
(this study)

*Compare to OGS-82-3. Similar facies are present, but in Cons. Pan Am 13057, Lucas facies are thinner, muddier(?), and less distinct, possibly reflecting proximity to Lucas pinchout. Gradational lower contact with Amherstburg.

Dundee Fm.

90.0 - 92.5m	Unit 1 - Dundee Facies 2(?).
92.5 - 95.7m	Unit 2 - Dundee Facies 3.

Lucas Fm.

95.7 - 96.3m	Unit 3 - greenish brown bioclastic wackestone-packstone-mudstone with crinoid, echinoderm, brachiopod and coral fragments.
96.3 - 99.9m	Unit 4 - consists of 3, oil-stained, fining-upward cycles (averaging 1.5 m thick). In each cycle, lower half = yellow brown floatstone (mudstone-wackestone matrix) with rounded, laminar and stick stromatoporoids, stromatoporoid-encrusted rugose corals, *Amphipora*, brachiopods, and gastropods. Upper half = light grey peloidal, bioclastic packstone-mudstone to micritic mudstone with common fine peloids and occasional laminar stromatoporoids, rugose and thamnoporid corals, gastropods; slightly fenestral; *Amphipora* and laminar stromatoporoid rudstone-bindstone intervals. Possible desiccation cracks at top of unit.
99.9 - 107.6m	Unit 5 - greenish brown bioclastic, peloidal packstone to floatstone (*Amphipora*, rugose corals, stromatoporoids, gastropods, ostracods); occasional laminar stromatoporoids; upwards, becomes muddier and bioclastics, coarser; wispy organic seams. Two, 50 cm thick intervals (at 99.9 and 103.1m) of dark brown, stromatoporoid (*Amphipora*, tabular, stick, laminar) and thamnoporid rudstone-bindstone in wackestone matrix, with organic seams.
107.6 - 109.6m	Unit 6 - greenish brown, well sorted, peloidal-bioclastic grainstone/packstone to floatstone, with *Amphipora*, brachiopods, rugose corals, laminar stromatoporoids, echinoderm spines/fragments, ostracods; occasionally fenestral; 2 to 3 cm thick intervals of laminar stromatoporoid boundstones.

Amherstburg Fm.

109.6 - 110.2m	Unit 7 - brown-dark brown *Amphipora*-laminar stromatoporoid-thamnoporid floatstone-boundstone with pulses of *Amphipora* rudstone with numerous organic seams.
110.2 - 111.9m	Unit 8 - greenish brown *Amphipora*, stromatoporoid-encrusted thamnoporid, stick stromatoporoid rudstone with micritic matrix; occasional rounded stromatoporoids; spherical and massive stromatoporoid (15 to 20 cm) at 110.9m.
111.9 - 112.2m	Unit 9 - massive coral and stromatoporoid boundstone.
112.2 - 112.5m	Unit 10 - laminar stromatoporoid, *Amphipora*, rugose coral, echinoid fragment boundstone with dark brown mudstone matrix.
112.5 - 120.4m	Unit 11 - consists of three, ~2.5m thick, fining (muddying) upward cycles, with fossil size increasing upward. Lower part generally a dark brown-brown echinoid-crinoid-rugose coral wackestone to rugose and thamnoporid coral-stromatoporoid floatstone with echinoid/crinoid fragment matrix. Upper, a dark brown, massive to horizontal-laminated, echinoid-crinoid-ostracod-brachiopod fragment mudstone.
120.4 - 121.2m	Unit 12 - brown-grey thamnoporid and rugose coral-brachiopod fragment floatstone in an echinoid-crinoid-coral fragment grainstone matrix.
121.2 - 123.3m	Unit 13 - dark brown rugose and thamnoporid coral-echinoid-gastropod floatstone grading upward to a rudstone; floatstone set in echinoid-coral bioclastic mudstone-wackestone matrix; laminar stromatoporoid intervals; occasional organic seams.
123.3 - 128.0m	Unit 14 - dark brown echinoderm fragment wackestone to rugose and thamnoporid coral-*Amphipora* floatstone set in echinoderm (plates/stems) mudstone-wackestone matrix; frequent organic seams; occasional large (3 to 10 cm diameter) massive and rugose corals; occasional thin (3 cm) laminar stromatoporoid bindstone intervals.

CONSOLIDATED WEST CT - 1
Lake Erie 234 - M
(Core #117)

Drill Hole 5
(this study)

Dundee Fm.	
60.0 - 62.0m	Unit 1 - muddy, slightly argillaceous, bioclastic wackestone-packstone-grainstone.
62.0 - 63.1m	Unit 2 - peloidal packstone-grainstone.
Lucas Fm.	
63.1 - 64.2m	Unit 3 - grey to tan to brown, thinly bedded, graded silty mudstone to mudstone with sparse assorted grey, white, and blackened quartz grains; convoluted mudstone beds 10 cm from top.
64.2 - 64.7m	Unit 4 - brown massive stromatoporoid-coral floatstone in mudstone matrix.
64.7 - 65.6m	Unit 5 - tan to cream-coloured, massive micritic mudstone; very fine peloidal grainstone.
65.6 - 66.5m	Unit 6 - tan massive, silty peloidal mudstone grading to peloidal, ostracod-rich packstone-grainstone. Minor thin laminations. Near top, floatstone pulses with ostracods, rugose corals, rounded stromatoporoids, stromatoporoid-encrusted corals, and laminar stromatoporoid fragments.
66.5 - 67.1m	Unit 7 - grey to brown, laminated to thin-bedded, finely crystalline lime mudstone. Minor convolute laminations.
67.1 - 67.8m	Unit 8 - brown, massive, fasciculate to small bulbous stromatoporoid floatstone; uncommon irregular stromatoporoids and coral fragments.
67.8 - 69.4m	Unit 9 - greenish-grey, laminated sandstone-siltstone grading up to tan, massive, micritic mudstone and silty peloidal lime mudstone. Top 30 cm - silty peloidal grainstone with about 10% ostracods and crinoids.
69.4 - 70.6m	Unit 10 - brown, massive stromatoporoid coral wackestone to floatstone; common robust fasciculate stromatoporoid branches. Rare brachiopods. Uncommon irregular stromatoporoids and coral fragments. Rare charophyte oogonia at ~69.49 m; black carbonaceous laminae at base.
70.6 71.3m	Unit 11 - peloidal packstone-grainstone, with about 20% ostracods in lower 30 cm. Stromatoporoid-encrusted rugose coral and thamnoporid floatstone in upper 20 cm.
71.3 - 71.7m	Unit 12 - thin-bedded, tan mudstone.
71.7 - 72.1m	Unit 13 - brown stromatoporoid-coral rudstone; common dendritic stromatoporoid branches, tabulate coral (*Hexagonaria*?), and tabular stromatoporoid fragments and colonial rugose coral fragments.
72.1 - 73.2m	Unit 14 - tan to light grey to light brown, thinly bedded to laminated mudstone; very thin carbonaceous seams and rare intraclasts; mottled zone at ~72.85 m. Minor ostracods in upper third.
73.2 - 74.2m	Unit 15 - dark brown-brown, massive, sparsely fossiliferous lime wackestone-floatstone; occasional sparsely sandy, stromatoporoid-coral pulses (bioclastic floatstones).
74.2 - 74.6m	Unit 16 - peloidal, gastropod-rich packstone-grainstone; lower sandy erosive contact. Borings(?) infilled with sand. In lower 10 cm, brachiopod-*Amphipora*-gastropod floatstone.
74.6 - 76.2m	Unit 17 - tan to grey to light brown, massive to thin- and convolute-bedded, sparsely fossiliferous lime mudstone; fenestral mudstone at top of unit.
76.2 - 77.6m	Unit 18 - brown, fine-crystalline stromatoporoid-coral boundstone to floatstone; common robust fasciculate stromatoporoid branches, uncommon *Amphipora* and stromatoporoid-encrusted colonial rugose coral branches; sparsely sandy and peloidal.
77.6 - 79.7m	Unit 19 - tan to light grey, thin-bedded, sparsely fossiliferous lime mudstone grading up to massive, medium-bedded, sparsely fossiliferous, fine-crystalline mudstone-wackestone.
79.7 - 81.3m	Unit 20 - brown thamnoporid, stromatoporoid floatstone pulses interbedded with thin- to medium-bedded, nonfossiliferous lime mudstone. Moderately fossiliferous pulses have robust thamnoporid corals and less common small, irregular stromatoporoids and colonial rugose coral fragments. Rare gastropods.
	—base of core—

CONSOLIDATED WEST CT - 6
Lake Erie 234-L
(Core #113)

Drill Hole 76
(this study)

*oil stained; may affect dolomitization estimates

Dundee Fm.

63.0 - 64.9m	Unit 1 - tan bioclastic packstone-grainstone-floatstone with rounded and laminar stromatoporoids, and stromatoporoid-encrusted rugose corals.

Lucas Fm.

64.9 - 65.4m	Unit 2 - peloidal, bioclastic packstone grading up to grey, thin-laminated mudstone; top 15 cm is a grey, disrupted, fenestral, peloidal (15%), algal mudstone.
65.4 - 66.2m	Unit 3 - tan, porous, very thinly laminated, very fine- to fine peloidal (some fecal pellets) grainstone; occasional laminar stromatoporoids. Mottled, nodular layer at 65.7 m.
66.2 - 66.9m	Unit 4 - tan wackestone-packstone with occasional stromatoporoids, ostracods and echinoderms, grading and fining upward into a grey, bioclastic mudstone-wackestone. Occasional pulses of rugose corals and *Amphipora*.
66.9 - 67.5m	Unit 5 - grey, slightly fenestral, sandy (fine- to medium-grained quartz), very fine peloidal, algal, micritic mudstone; rare gastropods. Frequency of peloidal layers decreases upwards; top 23 cm appears disrupted. Carbonaceous seam at lower contact.
67.5 - 69.2m	Unit 6 - predominantly a tan, sandy (5 to 10%) bioclastic wackestone-packstone with crinoid, brachiopod and gastropod fragments; intervals of massive, laminar, tabular and rounded stromatoporoid-*Amphipora* floatstone. At 67.8 m - porous, very fine to fine peloidal (some fecal pellets) grainstone with brachiopod, trilobite and gastropod fragments.
69.2 - 69.5m	Unit 7 - fine peloidal (and fecal), sandy wackestone.
69.5 - 70.0m	Unit 8 - grey to light brown, sandy (fine-grained) stromatolitic mound; very thinly laminated.
70.0 - 70.7	Unit 9 - tan, sandy, peloidal, algal mudstone; ostracods; grades upward into bioclastic, sandy wackestone with occasional laminar stromatoporoids and stromatoporoid-encrusted *Amphipora*.
70.7 - 70.9m	Unit 10 - very fine peloidal (some fecal pellets) grainstone to gastropod-brachiopod floatstone with grainstone matrix. <5% well-rounded, medium-grained quartz sand.
70.9 - 72.3m	Unit 11 - grey to tan, sandy (<5%), laminar-tabular-dendritic stromatoporoid boundstone in mudstone matrix with occasional brachiopods, rugose, thamnoporids, stromatoporoid-encrusted corals and gastropods; increasing mud upwards; intervals of bioclastic packstone-rudstone, with rounded stromatoporoids, corals, brachiopods, *Amphipora*.
72.3 - 72.6m	Unit 12 - tan, fine peloidal (60 to 70%), irregular- to algal-laminated packstone-grainstone with about 10 to 20% subrounded quartz sand; 2 x 20 mm intraclast and ripple cross-laminations; carbonaceous seam at top.

—base of core—

LEESA-IMPERIAL 1-13-I
Lambton Co., Brooke Tp.; Lot 13, Conc. I
(Core #546)

Drill Hole 19
(this study)

Dundee Fm.	
115.0 - 118.8m	Unit 1 - Dundee Facies 2.
Lucas Fm.	
118.8 - 120.1m	Unit 2 - tan to light brown to greyish blue-mottled, massive, micritic lime mudstone.
120.1 - 120.6m	Unit 3 - sparsely sandy coral-stromatoporoid fragment bioclastic rudstone.
120.6 - 121.3m	Unit 4 - thin-bedded, brown micritic mudstone interbedded with massive sandy mudstone.
121.3 - 124.8m	Unit 5 - tan to light brown to greyish blue-mottled, massive, micritic lime mudstone. Recrystallized to some degree but not dolomitized; irregularly stylolitized and fractured.
124.8 - 125.3m	Unit 6 - tan, stromatoporoid-coral bioclastic rudstone.
125.3 - 126.7m	Unit 7 - stromatoporoid-coral rudstone; common massive and dendritic stromatoporoid fragments, fractured and abraded. Uncommon robust *Amphipora*; common abraded fragments of thamnoporid, colonial rugose (*Synaptophyllum*) and solitary rugose coral. (*Cystiphyllum*).
126.7 - 126.8m	Unit 8 - tan, laminated, micritic and massive, tan to cream, fine-crystalline sandy wackestone.
126.8 - 127.6m	Unit 9 - thamnoporid, stromatoporoid-encrusted *Synaptophyllum*, and robust *Amphipora* rudstone sharply overlain by 20 cm of sandstone.
127.6 - 129.3m	Unit 10 - medium-bedded, brown lime mudstone with black argillaceous seams; rare in-situ *Aulopora* and thamnoporid branches present; sparsely sandy with very fine- to fine-grained, rounded to subrounded quartz grains.
129.3 - 129.9m	Unit 11 - thamnoporid-*Synaptophyllum*, sandy bioclastic (abraded fossils common) rudstone; grades upwards to unit 10.
129.9 - 130.2m	Unit 12 - grey, sandy, fenestral peloidal grainstone.
130.2 - 133.8m	Unit 13 - tan to grey, oil-stained, clean quartz sandstone with thinly bedded to laminated angular micritic limestone clasts; grades upward to sandstone with limestone stringers then laminated lime mudstone with sandstone stringers. Calcite cemented, intergranular porosity.
133.8 - 137.0m	Unit 14 - massive, brown, fine-crystalline lime mudstone with thin moderately fossiliferous pulses (stromatoporoid-encrusted *Synaptophyllum*); grades upward to tan to cream, laminated micritic limestone; sparsely sandy with fine, rounded quartz grains. Upper part - tan- to grey-mottled, dolomitic peloidal mudstone.
137.0 - 138.2m	Unit 15 - tan to light grey, thin- to medium-bedded to laminated, sparsely sandy lime mudstone and dense micritic limestone. Darker brown, medium-bedded mudstone pulses (about 3 to 5 cm thick) with sorted, abraded *Amphipora* sticks; pulses in channels(?). Tan- to grey-mottled peloidal packstone(?) pulses, slightly dolomitic.

LEESA-DAWN 19-XIII
Lambton Co., Dawn Tp.; Lot 19, Conc. XIII
(Core #383)

Drill Hole 46
(this study)

*entire core oil saturated and glycerine-treated, making degree of dolomitization difficult to determine.

Dundee Fm.

96.9 - 100.7m Unit 1 - Dundee Facies 2.

Lucas Fm. (Anderdon Mb.)

100.7 - 102.4m Unit 2 - light brown, fine-grained sandy wackestone-packstone-grainstone; 5 cm thick pulses of *Amphipora* rudstone/floatstone set in sandy wackestone matrix; rare massive/domal stromatoporoid; occasion very thin bedded intervals.

102.4 - 103.0m Unit 3 - massive, sandy dolomudstone/dolomitic sandstone. *Amphipora* floatstone at top.

103.0 - 103.7m Unit 4 - buff to brown, silty to sandy, slightly wispy argillaceous wackestone; rounded fossil fragments; rare *Amphipora*. Thin carbonaceous seam at base.

103.7 - 104.2m Unit 5 - sandy lime mudstone. Top 10 cm - light grey sandy peloidal grainstone with sandy wavy seams. Gradational contact with unit 6.

104.2 - 106.9m Unit 6 - brown, horizontal, cross- to low-angle cross-stratified, fine- to medium-grained, moderately to weakly bioturbated calcareous/dolomitic quartz sandstone; rare brachiopods; *Skolithos* burrows.

106.9 - 108.8m Unit 7 - buff thamnoporid floatstone set in silty to fine sand, dolomitic lime mudstone-wackestone matrix. Gastropods, ostracods, bivalves also present. Upwards, becomes sandier, coral abundance increases while those of other fossils decreases. *Amphipora* and rounded stromatoporoids at top.

—end of core—

LEESA-IMPERIAL 4-27-XIII
Lambton Co., Dawn Tp.; Lot 27, Conc. XIII
(Core #590)

Drill Hole 9
(this study)

Dundee Fm.

120.0 - 125.8m	Unit 1 - Dundee Facies 2.

Lucas Fm.

125.8 - 127.2m	Unit 2 - stromatoporoid-coral bioclastic rudstone. Tabular, dendritic stromatoporoid clasts, thamnoporid and stromatoporoid-encrusted colonial rugose fragments common.
127.2 - 127.8m	Unit 3 - dark brown massive mudstone.
127.8 - 130.8m	Unit 4 - tan to light grey to bluish, sparsely sandy, mottled, brecciated and irregularly stylolitized, moderately fossiliferous mudstone-floatstone. Massive to varved(?)/thin laminated mudstone beds. Dendritic and tabular stromatoporoid clasts; coral fragments rounded to subangular in mudstone matrix. Burrow mottled(?).
130.8 - 131.4m	Unit 5 - dark brown *Amphipora* floatstone.
131.4 - 132.3m	Unit 6 - massive, dark brown, sparsely sandy, sparsely fossiliferous lime mudstone.
132.3 - 133.0m	Unit 7 - tan to light grey, fenestral peloidal grainstone with common planispiral gastropods; calcite-filled fenestrae very common; sparsely sandy.
133.0 - 134.4m	Unit 8 - massive, tan- to cream-coloured, very fine peloidal mudstone with small intraclasts.
134.4 - 137.3m	Unit 9 - tan to light brown to light grey calcareous sandstone grading to thinly bedded, tan, sandy lime mudstone and tan to grey, bluish-mottled, massive sandy mudstone; irregularly stylolitized/brecciated(?); rip-up mudstone clasts. Quartz sand very fine- to fine-grained, rounded to subangular.
137.3 - 139.3m	Unit 10 - sparsely sandy, stromatoporoid-coral floatstone-boundstone to rudstone. Common tabular and dendritic stromatoporoids, thamnoporid branches and uncommon stromatoporoid-encrusted *Synaptophyllum* branches. In-situ thamnoporid colony overlying stromatoporoid boundstone; *Aulopora* fragments. Oil stained.
139.3 - 140.2m	Unit 11 - tan, thin-bedded mudstone grading upward to laminated sandy mudstone and capped by cross-laminated calcareous sandstone (oil stained).
140.2 - 140.6m	Unit 12 - tan-grey, mottled dolomitic lime mudstone; slightly sandy; calcite-filled fenestrae.
140.6 - 143.3m	Unit 13 - tan to light brown, laminated to thinly bedded, micritic lime mudstone with darker laminae and stylolitic seams; sandy mudstone lenses to up to ~40 cm thick, decreasing sand content upward; fine-grained, rounded quartz sands; sparsely fossiliferous with uncommon small planispiral gastropods. Well sorted clean sands abut against stromatolite mound.

—base of core—

IMPERIAL 831
Lambton Co., Enniskillen Tp.; Lot 18, Conc. I
(Core #595)

Drill Hole 10
(this study)

Dundee Fm.

100.0 - 102.0	Unit 1 - Dundee Facies 2.

Lucas Fm.

102.0 - 109.0m	Unit 2 - tan to brown, thinly bedded to laminated, algal-fenestral, slightly dolomitic, microcrystalline lime mudstone with dark carbonaceous seams. (Typical Lucas - laminated facies.)
109.0 - 110.4m	Unit 3 - tan to brown, thinly bedded to laminated, microcrystalline lime mudstone; leached anhydrite laths.
110.4 - 111.5m	Unit 4 - brown, slightly argillaceous, sparsely fossiliferous lime wackestone; rare to uncommon crinoid, thamnoporid fragments.
111.5 - 112.3m	Unit 5 - massive, sparsely sandy lime wackestone; <20% sand/silt.
112.3 - 117.9m	Unit 6 - massive, tan-light brown, sparsely fossiliferous, possibly peloidal, slightly dolomitic lime wackestone interbedded with thinly bedded microcrystalline dolomudstone. Approximately 5 cm thick bioclastic floatstone bed with tabular stromatoporoids, dendritic stromatoporoid fragments, and stromatoporoid-encrusted colonial rugose corals. Tabular stromatoporoid ripped up and eroded.
117.9 - 118.6m	Unit 7 - bluish grey to white, zebra-mottled, dolomitic(?) lime mudstone; recrystallized and dedolomitized(?). Leached skeletal fragments.
118.6 - 120.6m	Unit 8 - medium-bedded, sparsely fossiliferous lime wackestone; slightly silty, peloidal with rare intraclasts at top.
120.6 - 124.0m	Unit 9 - tan to light brown, thinly bedded and laminated, to massive, tan-coloured, peloidal lime mudstone. Massive mudstone in middle and top of unit, dolomitic. Tan-grey-bluish mottled, recrystallized lime mudstone-wackestone with partially dissolved mudstone clasts. Sparsely to nonfossiliferous.
124.0 - 124.2m	Unit 10 - silty, peloidal lime mudstone; common (~60%+) fine peloids.
124.2 - 126.9m	Unit 11 - tan to light brown, massive, slightly wispy lime mudstone. Nonfossiliferous. Very fine-crystalline dolomudstone in middle of unit.
126.9 - 127.1m	Unit 12 - tan to brown laminated dolo-mudstone.
127.1 - 127.3m	Unit 13 - tan, massive lime mudstone.
127.3 - 127.5m	Unit 14 - tan to grey to bluish mottled, recrystallized lime mudstone-wackestone.
127.5 - 128.8m	Unit 15 - ostracod-rich bioclastic wackestone to floatstone. Common ostracod valves, rare *Amphipora*.
128.8 - 130.0m	Unit 16 - tan to light brown, thinly bedded to laminated, microcrystalline dolostone. (Typical Lucas facies.)

IMPERIAL 838
Lambton Co., Enniskillen Tp.; Lot 18, Conc. II
(Core #605)

Drill Hole 11
(this study)

Dundee Fm.	
91.0 - 92.2m	Unit 1 - Dundee Facies 2.
Lucas Fm.	
92.2 - 100.1m	Unit 2 - laminated microcrystalline mudstone.
100.1 - 100.3m	Unit 3 - dendritic to tabular stromatoporoid rudstone-floatstone.
100.3 - 100.6m	Unit 4 - laminated mudstone.
100.6 - 101.3m	Unit 5 - peloidal packstone-grainstone with subrounded to subangular sand/silt ~<10%.
101.3 - 105.1m	Unit 6 - tan to brown, thinly bedded to laminated, slightly dolomitic, microcrystalline lime mudstone with occasional thin intraformational breccias.
105.1 - 106.0m	Unit 7 - stromatoporoid-coral bioclastic rudstone-floatstone. Common tabular and dendritic stromatoporoid fragments. *Aulopora* fragments common; disarticulated ostracod valves also common. Sparsely sandy.
106.0 - 107.5m	Unit 8 - tan to brown, sparsely peloidal, microcrystalline dolomitic mudstone.
107.5 - 107.8m	Unit 9 - bluish grey to tan mottled dolomudstone; zebra mottled(?).
107.8 - 110.3m	Unit 10 - tan to brown, thinly bedded to laminated dolomudstone with thin peloidal packstone pulse.
110.3 - 110.5m	Unit 11 - tan to bluish grey, mottled, fenestral dolomitic mudstone; zebra dolomitic(?).
110.5 - 111.15m	Unit 12 - tan to brown, thinly bedded to laminated, algal dolomudstone; thin brecciated interval.
111.15 - 118.8m	Unit 13 - tan to light brown, heavily oil-stained, massive- to medium-bedded, sparsely peloidal, microcrystalline dolomitic mudstone.
118.8 - 120.1m	Unit 14 - tan peloidal mudstone-packstone-grainstone.
120.1 - 121.0m	Unit 15 - tan-brown, fasciculate to thin tabular stromatoporoid floatstone.
	—base of core—

NYK OIL MONROE No. 1
Lambton Co., Euphemia Tp.; Lot 27, Conc. IV
(Tray No. 6457)

Drill Hole 143
(this study)

*N.B.: Core not available; description based on core chip samples taken at 1.5 m intervals.

Dundee Fm.

95.8 - 98.6m	Unit 1 - tan, crinoidal, bioclastic grainstone-wackestone-packstone; Dundee Facies 2.

Lucas Fm. (Anderdon Mb.)

98.6 - 100.1m	Unit 2 - grey, nonfossiliferous dolomudstone. About 1% fine organic fragments; trace of pyrite.
100.1 - 101.6m	Unit 3 - tan, sandy, bioclastic grainstone-packstone with micritic matrix; stringers of rounded, very fine- to fine-grained quartz sand (70 to 80% of framework), constituting 10 to 20% of unit overall; carbonaceous seams.
101.6 - 103.2m	Unit 4 - tan, fine-grained, bioclastic, peloidal(?), algal(?) packstone with micritic matrix; possible crinoid fragments; 5 to 10% rounded, frosted, fine-grained quartz sand.
103.2 - 106.2m	Unit 5 - tan, sandy calcareous sandstone to sandy micritic limestone; sand consists of medium- to coarse-grained, rounded to well rounded, poorly to moderately sorted, frosted/pitted quartz grains, constituting 70 to 95% of rock in lower part to ~10 to 20% (occurring in stringers) in upper, micritic limestone intervals. Oil stained.
106.2 - 107.7m	Unit 6 - light brown, sandy, bioclastic and pelletal (10 to 20%) packstone-grainstone with occasional rugose coral and echinoderm fragments; 10 to 20% subangular to subrounded, fine-grained quartz sand. Oil stained.
107.7 - 109.3m	Unit 7 - brownish grey, sandy, pelletal, bioclastic, algal(?) grainstone-packstone-wackestone with a dolomudstone matrix; fine laminations; <5% fine-grained, subrounded to subangular quartz sand; some echinoderm fragments; common organic seams.
109.3 - 110.7m	Unit 8 - grey, fine peloidal grainstone; common (up to 30%) fine-grained, rounded, frosted quartz sand occurring as stringers; rare micritic intraclasts.

—end of samples—

ARGOR 65-1
Lambton Co., Moore Tp.; Lot 28, Conc. II
(Core #538)

Drill Hole 12
(this study)

Dundee Fm.

245.0 - 248.6m	Dundee Facies 2

Lucas Fm.

248.6 - 251.7m	Unit 1 - tan to light brown, light grey, massive to medium-bedded, nonfossiliferous lime mudstone to sparsely fossiliferous wackestone to floatstone and thin stromatolitic mound mudstone. Rare tabular stromatoporoid, thamnoporid and *Aulopora* fragments; uncommon *Tasmanites*; ~10 cm thick algal mound at ~240.0 m. Very fine to fine intercrystalline porosity.
251.7 - 251.9m	Unit 2 - massive mudstone with tan, laminated mudstone intraclasts.
251.9 - 253.0m	Unit 3 - tan, laminated, peloidal(?) mudstone-packstone. Anhydrite laths. Interpelletoid porosity. Thin black clay seam at base.
253.0 - 253.6m	Unit 4 - grey, massive mudstone; ~4 cm mottled below clay seam. Lower 30 cm tan to grey brecciated zone with tan clasts in grey, pyritic mudstone matrix.
253.6 - 254.2m	Unit 5 - brown-dark brown, laminated to thinly bedded mudstone.
254.2 - 256.6m	Unit 6 - light grey to tan, thinly bedded to massive dolomudstone.

ARGOR 65-1, continued

256.6 - 258.6m	Unit 7 - light grey to tan, laminated to thinly bedded lime mudstone and peloidal packstone in top 1.5 m. Thinly bedded dolomudstone at base.
258.6 - 260.9m	Unit 8 - tan, massively bedded to grey-tan, thinly bedded nonfossiliferous, possibly sparsely peloidal dolomudstone with thin peloidal packstone pulses(?).
260.9 - 262.6m	Unit 9 - tan to brown, thinly bedded to massive, nonfossiliferous, finely crystalline dolomudstone. Good intercrystalline porosity. Uncommon small (<2 cm diameter) calcite nodules.
262.6 - 265.5m	Unit 10 - brown, massive dolomitic wackestone-floatstone(?) with white, coarse calcite void-filling nodules (~5%); gastropod molds (~1 to 2 cm turbinate gastropods). Good porosity (vuggy to moldic). Medium to coarse crystalline; possibly peloidal/algal packstone-grainstone at base.
265.5 - 267.5m	Unit 11 - tan to light grey to light brown, thin- to medium-bedded, nonfossiliferous, fine- to very fine-crystalline dolomitic mudstone with rare mudstone rip-up clasts.
267.5 - 269.7m	Unit 12 - tan to light grey, nonfossiliferous, massive, micritic dolomudstone interbedded with tan to grey to light brown, very fine- to fine-crystalline, thinly bedded dolomudstone. Upper 30 cm - grey to bluish mottled mudstone, slightly pyritic.
269.7 - 270.8m	Unit 13 - massive, brown, porous, vuggy wackestone(?) with rare anhydrite cement.
270.8 - 274.0m	Unit 14 - tan, massive, micritic to very fine-crystalline dolomudstone.
274.0 - 275.0m	Unit 15 - grey-brown dolomudstone with abundant thick coarse secondary anhydrite. Common fibrous and tabular laths bounding dolostone (gypsiferous).
275.0 - 279.8m	Unit 16 - tan to grey to light brown, medium-bedded, massive, microcrystalline to very finely crystalline dolomudstone interbedded with porous, peloidal(?), moldic(?), massive packstone to mudstone. Some vug-filling secondary anhydrite (<10%). Lower 50 cm has common anhydrite laths.
279.9 - 282.1m	Unit 17 - in upper part of unit, coarse secondary anhydrite with lath pseudomorphs bounding dolostone beds (recrystallized). Tan-grey, massive dolomudstone with anhydrite laths and uncommon small nodules.
282.1 - 284.4m	Unit 18 - brown, finely crystalline, medium-bedded to massive, sparsely fossiliferous, pinpoint vuggy dolowackestone-floatstone(?). Fossils replaced by secondary anhydrite; evidence of common small ostracods/bivalves(?); ~15 cm intraformational conglomerate at base of unit.
284.4 - 288.0m	Unit 19 - tan-brown dolomudstone (10 to 20%) with coarse bluish white anhydrite. Part looks like chicken-wire texture (anhydrite ~80%).
288.0 - 292.8m	Unit 20 - tan-brown to dark brown, massive, medium and thinly bedded dolomudstone. Basal massive dolomudstone with anhydrite laths grade into medium and thinly bedded, possibly peloidal dolomitic packstone-mudstone. Small vuggy and fine intercrystalline porosity.
292.8 - 298.1m	Unit 21 - tan to light brown and grey, thinly bedded dolomudstone (~20%) and massive coarse secondary anhydrite (~80%).
298.1 - 304.6m	Unit 22 - tan to brown, thinly bedded and laminated to medium-bedded, homogeneous dolomudstone. Nonfossiliferous. Possibly sparsely peloidal(?). Leached anhydrite laths.
304.6 - 325.4m	Unit 23 - tan-light brown to grey laminated, thinly bedded and massive interbedded dolomudstones. Very fine to fine crystalline. Algal stromatolitic in places. Rare anhydrite nodules.
Amherstburg Fm.	
325.4 - 327.5m	Unit 24 - sharp contact with *Amphipora*/stromatoporoid/coral rudstone to floatstone.

IMPERIAL #547
Lambton Co., Moore Tp.; Lot 10, Conc. IX
(Core #532)

Drill Hole 13
(this study)

Dundee Fm.	
165.0 - 172.3m	Unit 1 - Dundee Facies 2
Lucas Fm.	
172.3 - 174.7m	Unit 2 - tan, laminated to wispy, massive and medium-bedded lime mudstones.
174.7 - 178.0m	Unit 3 - massive, sparsely fossiliferous lime mudstone to wackestone; slightly wispy textures. Thin ~3 cm mottled mudstone (not vuggy) 20 cm above base of unit. Upper 1 m has uncommon *Amphipora* and tabular stromatoporoid bioclasts; rare *Synaptophyllum* fragments and ostracod valves.
178.0 - 178.6m	Unit 4 - tan-grey, vuggy, very porous, calcareous mudstone with mudstone clasts and common coarse spar.
178.6 - 178.8m	Unit 5 - laminated, algal, dolomitic lime mudstone.
178.8 - 181.4m	Unit 6 - tan-brown-dark brown, thinly laminated dolomitic mudstone interbedded with medium-bedded, very fine- to fine-crystalline dolomitic mudstone. Massive beds possibly peloidal(?).
181.4 - 182.5m	Unit 7 - tan, massive, dolomitic mudstone; uncommon wispy seams.
182.5 - 184.1m	Unit 8 - very fine- to fine-crystalline, laminated dolomudstone facies.
184.1 - 185.3m	Unit 9 - tan, massive, peloidal(?) packstone-mudstone with intercrystalline and organic (leached clasts/peloids) porosity.
185.3 - 185.5m	Unit 10 - tan to whitish, vuggy, porous limestone; caliche(?); coarse sparry calcite.
185.5 - 189.8m	Unit 11 - tan to brown, massive, sparsely peloidal, very finely crystalline dolomitic mudstone interbedded with thin-laminated dolomudstone. Occasional stromatolitic algal mounds in massive dolomudstone beds.
189.8 - 192.1m	Unit 12 - tan to brown, thinly bedded to laminated dolomudstone facies. (Typical laminated Lucas.)
	—base of core—

IMPERIAL 661 CORUNNA 18
Lambton Co., Moore Tp.; Lot 20, Conc. X
(Core #603)

Drill Hole 14
(this study)

Dundee Fm.	
190.0 - 192.1m	Unit 1 - Dundee Facies 2
Lucas Fm.	
192.1 - 198.3m	Unit 2 - tan to light brown, laminated to thinly bedded, nonfossiliferous to algal-laminated, microcrystalline lime mudstone with massive, sparsely fossiliferous wackestone bed in middle of unit. Wackestone has thin tabular in-situ stromatoporoids, stromatoporoid fragments and ostracod fragments. Very fine intercrystalline porosity.
198.3 - 198.7m	Unit 3 - tan, porous, massive lime mudstone with sulphur crystals.
198.7 - 214.2m	Unit 4 - tan to light brown, thinly bedded, laminated and occasionally algal-laminated, microcrystalline to very fine-crystalline dolomitic mudstone; dark laminae. Nonfossiliferous. Thin beds of dolomudstone with some anhydrite replacement and sulphur crystals.
214.2 - 214.9m	Unit 5 - dolomudstone with ~70% brown coarse anhydrite.
214.9 - 220.0m	Unit 6 - tan, thinly bedded dolomudstone.

OGS-82-1
Lambton Generating Station
Lambton Co., Moore Tp.; Lot 18, Conc. Front

Drill Hole 51
(this study)

Dundee Fm.

270.0 - 270.5m	Unit 1 - tan-brown bioclastic wackestone-packstone-floatstone with tabulate and thamnoporid corals, *Aulopora*(?), laminar stromatoporoids, bivalves, ostracods, *Amphipora*.
270.5 - 271.1m	Unit 2 - bioclastic, very fine peloidal grainstone with bryozoan fragments and *Aulopora*(?).
271.1 - 272.6m	Unit 3 - grey-tan, thick- to algal-laminated, dolomitic lime mudstone; rare tabulate corals; brecciated and disrupted in upper and lower (subaerial?--Lucas?) intervals. Small anhydrite nodules at base.

Lucas Fm.

272.6 - 274.0m	Unit 4 - tan-grey to brown, horizontal- to algal-laminated, dolomudstone to dolomicrite with rare gastropods, numerous organic seams, minor desiccation and bioturbation in lower half, and normally graded laminae; occasional calcite nodules.
274.0 - 274.9m	Unit 5 - tan, porous, soft, thin-bedded to thin-laminated, horizontal- to wavy-laminated dolomicrite-dolomudstone; uncommon *Tasmanites*; rare sulphur crystals, anhydrite laths; numerous organic seams and disturbed algal laminae near base.
274.9 - 276.9m	Unit 6 - grey to tan brown, thin- to thick-laminated dolomicrite/mudstone with numerous organic seams; laminae normally graded: coarse to fine crystalline; occasional carbonaceous layers, ripple cross-laminae, truncated laminae; algal-laminae, anhydrite laths near top; rare, 2 to 3 cm deep vertical burrows.
276.9 - 277.9m	Unit 7 - tan, soft, porous, coarse- to fine-crystalline, horizontally thick-laminated to thin-bedded dolomicrite; occasionally desiccated and severely fractured (with brown dolomudstone infills).
277.9 - 279.9m	Unit 8 - dark brown, moderately bioturbated(?), algal(?)-laminated dolomudstone with numerous organic seams; laminae become thicker and less distinct upward; ripple cross-laminae, desiccated/disturbed laminae and thorough bioturbation near top; rare black organic seams; contorted laminae and hardground(?) at base.
279.0 - 280.5m	Unit 9 - tan-grey mudstone-wackestone with ostracods, brachiopods, echinoderms, peloidal intraclasts, and minor thamnoporids and stromatoporoid(?) sticks.
280.5 - 281.5m	Unit 10 - brown, sparsely fossiliferous, irregularly laminated to massive mudstone-wackestone with numerous organic seams; rare brachiopods; carbonaceous seam at top.
281.5 - 281.9m	Unit 11 - brown wackestone to rugose-thamnoporid floatstone set in ostracod-brachiopod wackestone matrix; some corals stromatoporoid encrusted; occasional laminar stromatoporoids.
281.9 - 283.5m	Unit 12 - tan, very thin- to thick-laminated dolomudstone with weakly to thoroughly bioturbated, disrupted (desiccated?) and convoluted intervals; bioclastic (storm) layers at 282.2m. Tan-grey tabular stromatoporoid boundstone in upper 0.5 m.
283.5 - 283.8m	Unit 13 - massive anhydrite with interstitial dolomudstone and minor gypsum veins.
283.8 - 285.6m	Unit 14 - tan-grey, thickly laminated to massive dolomudstone with a few 10 cm intervals of fenestral dolomicrite; disrupted laminae at base.
285.6 - 289.0m	Unit 15 - tan to grey-brown, thin-laminated to thin-bedded, fine-crystalline dolomudstone grading up to very thin-bedded mudstone-wackestone with crinoids(?), *Amphipora*(?); weakly bioturbated; occasional intervals of fracturing, brecciation.
289.0 - 290.9m	Unit 16 - nodular to massive anhydrite (60 to 70%) with interstitial contorted/disrupted, laminated dolomudstone; gypsum laths and numerous gypsum veins.

OGS-82-1, continued

290.9 - 294.0m	Unit 17 - tan brown, massive, moderately to thoroughly bioturbated dolomudstone/dolowackestone with thin intervals of thin-laminations, occasionally disrupted; occasional brachiopods, anhydrite laths and gypsum- and calcite nodules. At 293.2m, interlaminated, horizontal- to low-angle cross-laminated, sandy, peloidal(?), dolomudstone and fine-grained sandstone; rare escape burrows(?).
294.0 - 295.4m	Unit 18 - grey, thin- to thick-laminated, nonfossiliferous, occasionally massive, contorted and desiccated(?) lime mudstone to dolomudstone; occasional wave(?) ripple cross-laminae (one ripple form-set).
295.4 - 296.2m	Unit 19 - blue-grey, nodular, mosaic and chickenwire anhydrite with interstitial massive to thickly laminated dolomudstone; gypsum laths.
296.2 - 298.4m	Unit 20 - tan-brown, interbedded algal dolomicrites and thin-bedded dolomudstones, displaying dish structures, disruption (possible desiccation?); occasional overturned laminae; hardground(?) and bioclastic (corals, brachiopods) packstone at 297.5m.
298.4 - 299.4m	Unit 21 - brown, massive to faintly laminated, moderately bioturbated, dolomudstone with gypsum nodules; gradational upper contact.
299.4 - 302.9m	Unit 22 - blue-grey, nodular/mosaic and chickenwire anhydrite with interstitial laminated to massive dolomudstone; uncommon anhydrite laths.
302.9 - 304.8m	Unit 23 - tan-brown, thickly horizontally laminated dolomudstone/dolomitic lime mudstone grading up into dolo-algal laminites; gradational upper contact.
304.8 - 306.1m	Unit 24 - tan brown, moderately to thoroughly bioturbated, thickly laminated calcareous dolomudstone-dolowackestone with occasional brachiopods and other unidentifiable fossils; wave ripple form-set at base.
306.1 - 307.8m	Unit 25 - tan-brown, massive to thickly laminated dolomudstone/micrite; fracturing and possible desiccation at 307.3m
307.8 - 312.1m	Unit 26 - blue-grey nodular to massive (some chickenwire) anhydrite with occasional intervals of nonfossiliferous, porous, thin-laminated dolomicrite/dolomudstone; gradational lower contact.
312.1 - 316.3m	Unit 27 - tan, porous, nonfossiliferous, thin-laminated to algal(?) laminated dolomudstone-dolomicrite. Algal-laminated intervals are brecciated (desiccated?), contain soft, claystone (some fragmented) interlayers, and variably alternating fine and coarse crystalline laminae; numerous organic seams. Dark grey mottling throughout.
316.3 - 316.9m	Unit 28 - tan, thin- to thick- and horizontal-laminated calcareous dolomudstone with discontinuous interlaminations/stringers of anhydrite and calcite; possibly peloidal; intraclasts in lower half.
316.9 - 317.6m	Unit 29 - tan, non- to recrystallized, very fine to coarse oolitic(?), peloidal grainstone/packstone-floatstone with horizontally oriented intraclasts, 10 to 20% fragmented brachiopods; variably dolomitized.
317.6 - 318.4m	Unit 30 - tan, algal-laminated dolomudstone; uncommon fine peloids; 1 cm thick intraclast layer.
318.4 - 320.0m	Unit 31 - tan-brown, weakly bioturbated, thin- to thick-laminated dolomudstone; some laminae truncated and overturned; occasional organic seams.
320.0 - 320.6m	Unit 32 - tan, medium-grained oolitic grainstone with occasional shell fragments and peloids; 10% scattered anhydrite lath masses. Similar to unit 29.
320.6 - 323.3m	Unit 33 - greyish tan to tan, weakly to moderately bioturbated, sparsely fossiliferous, thin- to thick- and horizontal-laminated (continuous to discontinuous) dolomudstone/dolomicrite with variably alternating fine and coarse crystalline layers; occasional anhydrite laths; intervals of frequent organic seams; possible algal laminae; interval of ostracod and shell fragment lime wackestone at top.

OGS-82-1, continued

323.3 - 324.4m	Unit 34 - tan-grey oolitic grainstone (same as unit 32) grading up into tan, moderately bioturbated, irregularly laminated dolomudstone and algal-laminated dolomudstone; desiccation cracks at top.
324.4 - 326.1m	Unit 35 - tan to tan-brown, massive to thinly bedded, sparsely fossiliferous, moderately to thoroughly bioturbated dolomudstone-wackestone with wispy organic seams, scattered brachiopods and 1 to 2 cm diameter anhydrite nodules; flattened anhydrite nodules on sharp, bottom contact.
326.1 - 327.0m	Unit 36 - tan-grey, fine to medium peloidal grainstone with occasional scattered shell fragments, lime micrite intraclasts (some imbricated), and 1 cm thick grey lime micrite interlayers; anhydrite laths; gradational lower contact.
327.0 - 330.4m	Unit 37 - tan-brown, massive to thin-bedded, moderately to thoroughly bioturbated dolomudstone-dolowackestone with numerous organic seams; anhydrite nodules at 329.3 m; 10 cm thick thoroughly disrupted interval at 328 m; similar to unit 35.
330.4 - 333.5m	Unit 38 - buff-brown, thickly laminated to thinly bedded to algal-laminated dolomudstone/dolomicrite; several intervals displaying scouring (up to 4 cm) of laminae overlain/filled by bioclastic (ostracod, brachiopod, gastropod and thamnoporid fragments) dolowackestones with flat-lying intraclasts; 50% of unit disrupted/brecciated (dewatering); rare thoroughly bioturbated layers; large (up to 5 cm deep) vertical burrows near top.
333.5 - 335.7m	Unit 39 - tan-brown to buff, indistinctly thin-bedded dolomudstone to massive, thoroughly bioturbated, bioclastic (10 to 30%) dolowackestone; brachiopod, ostracod and gastropod(?) fragments; scoured and disrupted laminae; frequent organic seams and celestite(?) nodules near top.
335.7 - 336.3m	Unit 40 - tan, peloidal, bioclastic grainstone/floatstone with 10 to 15% larger, dolomitized fragments of ostracods, brachiopods, *Amphipora*, thamnoporids; abundant diagenetic anhydrite laths; wave(?) ripple cross-laminations at top.
336.3 - 338.7m	Unit 41 - tan to tan-grey, irregular, wavy and discontinuous laminated to algal-laminated dolomudstone; non-algal intervals commonly contain crinoid and brachiopod fragments, and display flat pebble conglomerate textures and wave rippling; intervals of bioclastic (crinoids, gastropods, brachiopods) dolowackestone; algal laminae occasionally bioturbated/disturbed; clotted fenestral micrite with crinoids at 338.38; occasional organic seams; irregular, massive stromatoporoid at 337.9 m.
338.7 - 340.3m	Unit 42 - tan-brown, massive to wispy laminated bioclastic dolomudstone-wackestone-packstone with ostracod, coral, stromatoporoid, brachiopod, thamnoporid, and echinoderm fragments; peloidal in area; large massive-irregular stromatoporoid at 339.5m; organic seams more frequent near base.

Amherstburg Fm.

340.3 - 340.6m	Unit 43 - light brown, rugose coral-irregular and laminar stromatoporoid-*Amphipora*-stromatoporoid encrusted thamnoporid dolofloatstone in dolowackestone matrix.
340.6 - 341.5m	Unit 44 - brown *Amphipora* rudstone-boundstone with laminar, irregular, rounded and stick stromatoporoids, and stromatoporoid-encrusted corals; massive, domal stromatoporoids at base; numerous organic seams; uncommon brachiopods.
341.5 - 342.3m	Unit 45 - grey to black, rounded, tabular to lamellar stromatoporoid boundstone to *Amphipora*-rich rudstone with thamnoporids, lamellar, and stick stromatoporoids, and rugose corals; black organic seams constitute interstitial areas.
342.3 - 344.3m	Unit 46 - tan-brown, non- to moderately bioturbated tabular-irregular stromatoporoid boundstone with thamnoporids rounded stromatoporoids and rugose corals; dolomitized interstitial areas; anhydrite nodules and laths; numerous organic seams at base.

IMPERIAL 700 - REF. 11
Lambton Co., Sarnia Tp.; Lot 8, Range 2
(Core #601)

Drill Hole 20
(this study)

*For detailed lithologic description, see M.O.E. Deep Obs. #1 core, Lambton Co., Sarnia Tp.

Dundee Fm.	
180.0 - 182.5m	Unit 1 - Dundee Facies 2
Lucas Fm.	
182.5 - 188.4m	Unit 2 - massive micritic, to medium-bedded, sparsely fossiliferous, wispy dolomudstone-dolowackestone to lime mudstone-wackestone.
188.4 - 189.0m	Unit 3 - sulphur crystals in vuggy, porous, stromatolitic dolomudstone.
189.0 - 190.6m	Unit 4 - massive anhydrite.
190.6 - 192.1m	Unit 5 - horizontally veined, gypsiferous and anhydritic dolomudstone.
192.1 - 195.3m	Unit 6 - tan, laminated to thin-bedded dolomudstone.
195.3 - 206.0m	Unit 7 - predominately thin-bedded to laminated dolomudstone with some massive, very fine-crystalline beds. Zebra-mottling at top.
206.0 - 209.0m	Unit 8 - massive anhydrite.
209.0 - 219.5m	Unit 9 - medium-bedded to massive, very finely crystalline dolomudstone grading up to massive, grey-brown, finely crystalline dolomudstones to dolowackestones, then dark grey to brown to tan, laminated to algal-laminated dolomudstone.
219.5 - 224.3m	Unit 10 - massive anhydrite.
224.3 - 226.6m	Unit 11 - tan to grey, laminated to thin-bedded dolomudstone.
226.6 - 229.2m	Unit 12 - anhydritic dolomudstone.
229.2 - 234.7m	Unit 13 - thin- to medium-bedded, tan, fractured, homogeneous dolomudstone grading up to massive, wispy, very fine- to fine-crystalline dolomudstone.
234.7 - 240.0m	Unit 14 - massive to nodular anhydrite.

M.O.E. DEEP OBS. # 1
Lambton Co., Sarnia Tp.; Lot 12, Range 4
(Core #954)

Drill Hole 15
(this study)

Dundee Fm.	
180 - 183.4m	Dundee Facies 2.
Lucas Fm.	
183.4 - 190.2m	Unit 1 - thinly bedded and laminated, tan to brown, microcrystalline, stromatolitic lime mudstone interbedded with 10 to 20 cm thick massive, very finely crystalline, sparsely fossiliferous lime wackestone-floatstone beds. Rare brachiopods and coral fragments. Tabular stromatoporoid clast at ~188.0 m. (Oil stained).
190.2 - 190.4m	Unit 2 - ~15 cm thick grey-brown stromatolite mound with sulphur crystals.
190.4 - 191.6m	Unit 3 - massive, grey-brown anhydrite at base grading into a clotted and subhorizontally veined gypsiferous (satin spar) and anhydritic dolomitic. Upper unit is a laminated grey-brown anhydrite.
191.6 - 192.8m	Unit 4 - tan-brown algal-laminated dolomudstone.
192.8 - 193.85m	Unit 5 - laminated to subhorizontally veined (satin spar) gypsiferous dolomudstone and anhydrite.
193.85 - 196.6m	Unit 6 - tan to light brown, thinly bedded to algal-laminated dolomudstone. Minor distorted laminae.
196.6 - 197.3m	Unit 7 - tan to light grey, microlaminated and slumped dolomudstone/anhydrite - cottage cheese texture.
197.3 - 197.8m	Unit 8 - clotted grey-tan anhydrite.
197.8 - 206.3m	Unit 9 - tan-light brown, laminated to thinly bedded, very finely crystalline dolomudstone (oil stained) with dark carbonaceous laminae. Upper part of unit has light grey to tan, massive to very thinly laminated dolomudstone beds. Thin, bluish grey zebra-mottled dolomudstone at top of unit.
206.3 - 207.5m	Unit 10 - tan to light grey, thin- to medium-bedded, microfractured dolomudstone.
207.5 - 208.2m	Unit 11 - tan, laminated to distorted dolomudstone.
208.2 - 210.0m	Unit 12 - tan-grey, massive anhydritic dolomudstone (~60% anhydrite). Anhydrite and sulphur-filled fractures at top.
210.0 - 211.4m	Unit 13 - same as above (anhydritic dolomudstone).
211.4 - 215.5m	Unit 14 - tan to brown, massive, micro-cross-laminated and slumped/deformed(?) dolomudstone. Common anhydrite-filled fractures.
215.5 - 216.7m	Unit 15 - massive, tan, fractured, very porous dolomudstone. Excellent permeability.
216.7 - 221.2m	Unit 16 - grey-brown to greyish, massive to medium-bedded, sparsely fossiliferous, finely crystalline dolowackestone to thin-bedded dolomudstone. Uncommon brachiopods, *Amphipora* and thamnoporid coral fragments. <10% anhydrite-filled <2 cm diameter vugs.
221.2 - 222.7m	Unit 17 - massive to clotted grey-brown anhydrite with ~30% thin dolomudstone beds.
222.7 - 222.9m	Unit 18 - nodular anhydrite.
222.9 - 223.4m	Unit 19 - laminated dolomudstone and anhydrite.
223.4 - 224.2m	Unit 20 - massive replacive anhydrite.
224.2 - 224.7m	Unit 21 - white-bluish to brown nodular anhydrite.
224.7 - 225.6m	Unit 22 - tan to light brown, massive very thinly laminated to slumped dolomudstone; fractured with anhydrite infilling.

M.O.E. DEEP OBS. # 1, continued

225.6 - 226.6m	Unit 23 - tan, laminated dolomudstone; oil stained/fractured.
226.6 - 229.1m	Unit 24 - nodular to massive anhydrite in dolomudstone (~30%) matrix. Large tabular laths bounding dolomudstone pseudomorphed by anhydrite.
229.1 - 237.1m	Unit 25 - tan to light brown to greyish brown, thin- to medium-bedded to massive, finely crystalline dolomudstone. Common "floating" pseudomorphed anhydrite laths. Sparse small anhydrite nodules.
237.1 - 241.8m	Unit 26 - massive to nodular, white to greyish-blue anhydrite with ~10 to 20% brown dolomudstone beds.
241.8 - 249.1m	Unit 27 - tan to light brown, thinly bedded (oil-stained) to massive, very fine crystalline dolomudstone. Floating anhydrite laths common.
249.1 - 249.8m	Unit 28 - massive anhydrite and laminated dolomudstone.
249.8 - 262.3m	Unit 29 - tan to light brown, algal-laminated, microcrystalline dolomudstone with occasional massive dolomudstone beds. Dark carbonaceous laminae common. Uncommon small anhydrite laths. Some anhydrite replacement in lower few metres of unit. Anhydrite-filled, subvertical fractures common.
262.3 - 263.0m	Unit 30 - clotted anhydrite in dolomudstone matrix, possibly with clasts at top.
263.0 - 263.4m	Unit 31 - laminated dolomudstone; light grey to tan.
263.4 - 264.8m	Unit 32 - brown, dark brown-black laminated dolomudstone [restricted environment].
264.8 - 266.0m	Unit 33 - tan to light grey, very porous, thinly bedded dolomudstone; common thin anhydrite-filled vertical fractures.
266.0 - 273.3m	Unit 34 - light brown, wispy, massive, bioturbated dolomudstone, interbedded with light grey, massive to medium-bedded, very porous dolomudstone. Sparse, recrystallized robust thamnoporids at ~270.5 m. Anhydrite-filled fractures common. Hardgrounds at 266.8 and 272.7 m. Hardground surface with borings and overlying clasts at 272.7m.
273.3 - 278.3m	Unit 35 - tan to light brown, thinly laminated (very flat), microcrystalline dolomudstone.
278.3 - 281.6m	Unit 36 - brown, dark brown to black, wispy, bioturbated, sparsely fossiliferous dolomudstones and dolowackestones. Massive, medium bedded with rare anhydrite recrystallized fossils. Rare thamnoporid coral fragments. (Restricted lagoonal environment); dolomitic above 280 m.
Amherstburg Fm.	
281.6 - 283.4m	Unit 37 - dark brown-black stromatoporoid-coral bioclastic floatstone with thin tabular stromatoporoid boundstone pulse.
283.4 - 284.3m	Unit 38 - tabular stromatoporoid reef facies; boundstone.
	*Common to abundant tabulate corals in Amherstburg to ~290 m.

IMPERIAL 809
Middlesex Co., McGillivray Tp.; Lot 5, Conc. XIX
(Core #220)

Drill Hole 21
(this study)

Dundee Fm.	
	Dundee Facies 2
Lucas Fm.	
53.2 - 54.8m	Unit 1 - tan to light brown, algal-laminated, microcrystalline lime mudstone; peloidal(?)
54.8 - 55.2m	Unit 2 - tan to brown, massive, wispy stromatoporoid-coral wackestone to floatstone.
55.2 - 58.3m	Unit 3 - tan to brown, thinly bedded to algal-laminated, micro- to fine-crystalline lime mudstone. Leached anhydrite laths.
58.3 - 60.5m	Unit 4 - tan to brown to light grey, thinly bedded, laminated to algal-laminated, very fine crystalline dolomudstone; occasionally fine peloidal with peloid intraclasts. Anhydrite laths in massive beds.
60.5 - 61.2m	Unit 5 - laminated lime mudstone.
61.2 - 62.4m	Unit 6 - algal-laminated lime mudstone with clotted anhydrite mottles and thin, horizontal, satin spar-filled gypsum veins.
62.4 - 63.1m	Unit 7 - massive slumped dolomudstone with rare anhydrite.
63.1 - 66.8m	Unit 8 - brown to tan to greyish white dolomudstone and anhydrite. Anhydrite: thin, subhorizontally veined, massive and clotted textures; 50% anhydrite 50% dolomudstone.
	Upper 20 cm - tan to bluish grey, zebra-mottled dolomite.
66.8 - 67.8m	Unit 9 - tan, thin- to medium-bedded, very fine-crystalline dolomudstone.
67.8 - 74.4m	Unit 10 - tan to grey, laminated to massive lime mudstone; common anhydrite laths throughout. Thin, sparsely fossiliferous coral floatstone pulse at top of unit.
74.4 - 77.6m	Unit 11 - brown to grey, laminated to thin bedded dolomudstone; anhydrite cements.
77.6 - 80.0m	Unit 12 - brown, massive dolomudstone and grey-brown, veined to massive anhydrite (30 to 40% anhydrite).
80.0 - 82.0m	Unit 13 - tan-brown, faintly laminated, thin-bedded to massive, wispy, slightly dolomitic, micro- to very fine-crystalline lime mudstone. Common anhydrite laths in laminated sediments.
82.0 - 83.4m	Unit 14 - tan to light brown, massive, very fine-crystalline dolomudstone.
83.4 - 83.6m	Unit 15 - brown anhydrite.
83.6 - 84.7m	Unit 16 - grey to tan, thin-bedded dolomitic lime mudstone.
84.7 - 85.0m	Unit 17 - brown anhydrite.
85.0 - 85.7m	Unit 18 - tan to brown, laminated microcrystalline dolomudstone.
85.7 - 89.8m	Unit 19 - massive, grey-brown, finely crystalline, sparsely fossiliferous dolo-wackestone. Anhydrite replacing fossiliferous material; brachiopods, thamnoporid corals and small *Amphipora* uncommon.
89.8 - 91.4m	Unit 20 - grey to tan, thin-bedded dolomitic lime mudstone.
91.4 - 91.9m	Unit 21 - brown anhydrite.
91.9 - 95.4m	Unit 22 - predominately tan, thin-bedded, microcrystalline dolomudstone with occasional grey-brown laminated beds at base. *Tan laminites immediately below anhydrite.
95.4 - 97.5m	Unit 23 - interbedded greyish-brown and tan, thin-bedded to laminated microcrystalline dolomudstone.

IMPERIAL 809, continued

97.5 - 100.3m	Unit 24 - grey-brown, massive, wispy, partly bioturbated, finely crystalline, sparsely fossiliferous dolowackestone and dolomitic lime wackestone. Brachiopods, ostracods, coral fragments.
100.3 - 102.1m	Unit 25 - tan, thin- to medium-bedded dolomudstone.
102.1 - 106.4m	Unit 26 - white to bluish, nodular and massive anhydrite in a laminated brown dolomudstone matrix. ~80% anhydrite, <20% dolomudstone.
106.4 - 118.8m	Unit 27 - thin-bedded to massive, light tan dolomudstone with about 4 pulses of massive, tan to light grey, very fine- to fine-crystalline dolomudstone grading upward to dark brown and tan, thinly bedded to laminated microcrystalline dolomudstone. Uncommon, very small anhydrite laths in tan, laminated muds. Massive beds slightly wispy and bioturbated.
118.8 - 131.0m	Unit 28 - predominately tan, algal-laminated, microcrystalline dolomudstone with dark carbonaceous laminae. Thin, massive, finely crystalline dolomudstone-dolowackestone pulses. Rare <3 cm diameter anhydrite nodules in tan, algal dolomudstone in upper metre of unit. Rare anhydrite-filled fractures at base of unit.
131.0 - 131.5m	Unit 29 - laminated lime mudstone.
131.5 - 132.6m	Unit 30 - massive, finely crystalline, sparsely fossiliferous dolowackestone with small anhydrite-filled vugs.
132.6 - 135.1m	Unit 31 - dolomitic, moderately fossiliferous wackestone.
Amherstburg Fm.	
135.1 - 138.0m	Unit 32 - irregular stromatoporoid-coral boundstone-floatstone, dolomitic.
138.0 - 140.0m	Unit 33 - tabular stromatoporoid-reef facies.

EARL-BOLTON NO. 1
Middlesex Co., Metcalfe Tp.; Lot 6, Conc. II
(Tray No. 2097)

Drill Hole 147
(this study)

*N.B.: Core not available; description based on core chip samples taken at 3 m intervals.

Dundee Fm.

110.3 m	Dundee Facies 2 - brown, bioclastic packstone-wackestone; primarily crinoidal with minor brachiopod fragments; argillaceous seams; partially dolomitized matrix.
113.4 m	Dundee Facies 2/1(?) - bioclastic (crinoids, brachiopods) wackestone with sucrosic dolomudstone matrix and layers; more argillaceous than unit above.
116.4 m	Dundee Facies 2(?) - tan, bioclastic packstone-wackestone with predominantly crinoidal-brachiopod debris; occasional *Tasmanites*.

Lucas Fm.

119.5 m	Dark brown, thinly laminated, nonfossiliferous micritic mudstone with numerous carbonaceous seams; no *Tasmanites*.
122.5 m	Grey, slightly fenestral, nonfossiliferous, micritic mudstone with thin sucrosic dolostone interlaminations; sparse rounded and frosted fine quartz grains; speckled fine pyrite, occasionally concentrated in thin bands.
125.6 m	50% grey micritic mudstone similar to unit immediately above; 50% brown, thinly laminated, dense micritic mudstone; same as at 119.5 m except with less carbonaceous seams.
128.6 m	Brown, fine crystalline dolomudstone-dolowackestone with sparse flattened crinoids(?) and ostracod valves; 5% imbricated carbonaceous flakes.
131.7 m	Tan brown, sandy (20 to 30%; fine grained), argillaceous, bioclastic packstone-wackestone with fine crystalline dolomudstone matrix, interlaminated with tabular/laminar(?) stromatoporoids with galleries filled with quartz and peloids; oil stained; unit possibly a floatstone or boundstone.
134.7 m	70% tan, thin-laminated to massive, very fine-crystalline, nonfossiliferous dolomudstone; 30% grey, leached, tabular stromatoporoid fragments associated with stringers of fine peloidal grainstone; therefore, possibly a boundstone or floatstone; sulphur crystals; same as unit below.
137.8 m	Tan-grey, predominantly fine peloidal, minor echinoderm grainstone or a floatstone with grainstone matrix; 10% larger fossil fragments consisting of tabular and rugose corals, brachiopods, ostracods and trilobites(?); trace sulphur crystals.
140.2 m	Grey to tan, massive, porous, fine-crystalline dolomudstone; tan-coloured rock is more porous (vuggy, moldic).
142.2 m	Tan brown, nonfossiliferous, sucrosic, thin-laminated to massive dolomudstone with minor carbonaceous seams.

—end of core chip samples—

MITCHELL #3
Middlesex Co., Mosa Tp.; Lot 7, Conc. V
(Core #358)

Drill Hole 22
(this study)

Lucas Fm./Anderdon Mb.

113.1 - 113.5m	Unit 1 - tan-yellowish brown coral-stromatoporoid floatstone; common thamnoporids, uncommon small *Amphipora* and colonial rugose coral fragments (some stromatoporoid encrusted).
113.5 - 113.9m	Unit 2 - sandy stromatoporoid-coral floatstone to calcareous sandstone.
113.9 - 116.4m	Unit 3 - massive, planar to cross-stratified calcareous sandstone. Abundant well-rounded fine quartz sands.
116.4 - 116.8m	Unit 4 - sandy stromatoporoid-coral floatstone-sandstone; common robust fasciculate stromatoporoids.
116.8 - 117.3m	Unit 5 - sandy peloidal packstone-grainstone to peloidal sandstone.
117.3 - 118.3m	Unit 6 - light grey to bluish grey to tan, sandy, massive to thin-bedded (at top) lime mudstone with sandstone stringers.
118.3 - 119.4m	Unit 7 - *Amphipora* rudstone to peloidal packstone-grainstone; common *Amphipora* and colonial rugose coral fragments; uncommon tabular stromatoporoid fragments; *Aulopora*.
119.4 - 120.0m	Unit 8 - sandy peloidal lime wackestone; medium bedded, light brown-brown with dark carbonaceous seams.
120.0 - 120.6m	Unit 9 - sparsely sandy peloidal packstone-grainstone with mudstone intraclasts.
120.6 - 121.4m	Unit 10 - tan to light grey to bluish grey, thin-bedded grading up to massive, sandy lime mudstone, sparsely peloidal; thin sandstone stringers; zebra-mottled/fenestral at 121.0 m.
121.4 - 122.8m	Unit 11 - tan- to cream-coloured, laminated and thinly bedded lime mudstone grading up into medium-bedded, brown lime mudstone with dark brown carbonaceous seams.
	—base of core—

WALKER 502
Middlesex Co., Mosa Tp.; Lot 6, Conc. VI
(Core #895)

Drill Hole 23
(this study)

Lucas Fm./Anderdon Mb.

102.0 - 104.1m	Unit 1 - sparsely sandy lime wackestone with common peloidal grainstone pulses; *Aulopora* and small *Amphipora* present at top.
104.1 - 105.7m	Unit 2 - brown, tabular to domal stromatoporoid floatstone; sparsely sandy. Rare rugose corals.
105.7 - 107.5m	Unit 3 - tan to bluish-grey algal-peloidal packstone-grainstone; fenestral. Common *Leiosphaerids*.
107.5 - 109.4m	Unit 4 - bioclastic stromatoporoid-coral floatstone. Common thamnoporid and stromatoporoid-encrusted colonial rugose coral fragments; *Aulopora* fragments uncommon. Robust dendritic stromatoporoid branches. Rare mudstone clasts. Peloidal and sandy. Fine-grained wackestone matrix.
109.4 - 112.6m	Unit 5 - bioturbated, massive, planar and cross-stratified calcareous sandstone with well-rounded quartz grains.
112.6 - 113.4m	Unit 6 - stromatoporoid-coral fragment "bioclastic" floatstone to wackestone.
113.4 - 114.5m	Unit 7 - thin-bedded, brown sandy mudstone and tan micritic mudstone beds.
	—base of core—

ALLEGANY PROD. W. 112 **Drill Hole 24**
Middlesex Co., Mosa Tp., Lot 6, Conc. VI **(this study)**
(Core #302)

Dundee Fm.

103.9 - 107.5m	Dundee Facies 2.

Lucas Fm. (Anderdon Mb.)

107.5 - 110.2m	Unit 1 - Tan to brown, oil-stained, finely crystalline, massive lime mudstone. Sparsely fossiliferous. Light grey massive lime mudstone in upper 5 cm.
110.2 - 110.4m	Unit 2 - sparsely sandy, grey peloidal packstone-grainstone.
110.4 - 112.3m	Unit 3 - sparsely sandy, moderately fossiliferous "bioclastic" stromatoporoid-coral floatstone-wackestone. Common domal stromatoporoids, *Aulopora*, thamnoporid sticks. Finely crystalline; oil stained.
112.3 - 112.6m	Unit 4 - massive micritic mudstone.
112.6 - 113.2m	Unit 5 - sandy peloidal packstone/peloidal calcareous sandstone; common well-rounded quartz grains.
113.2 - 115.1m	Unit 6 - stromatoporoid-coral bioclastic wackestone-floatstone with thin sandy stringers.
115.1 - 118.8m	Unit 7 - massive, planar to cross-laminated calcareous sandstone. Abundant well-rounded, very fine- to fine-grained quartz sands.
118.8 - 119.5m	Unit 8 - sandy, moderately fossiliferous lime wackestone-packstone-grainstone.
119.5 - 120.2m	Unit 9 - tan, massive micritic lime mudstone.
120.2 - 121.2m	Unit 10 - tan-white sandy peloidal packstone.
	—base of core—

SECORD 601 **Drill Hole 25**
Middlesex Co., Mosa Tp.; Lot 6, Conc. VI **(this study)**
(Core #894)

Lucas Fm. (Anderdon Mb.)

98.1 - 99.5m	Unit 1 - oil-stained, very fine- to fine-crystalline, massive, wispy stromatoporoid floatstone. Sparsely sandy; uncommon stromatoporoid clasts, rare coral fragments.
99.5 - 102.0m	Unit 2 - tan to grey to light brown, sandy algal/peloidal packstones to grainstones. Common small peloids and common *Leiosphaerids*. Up to ~20% well-rounded, fine quartz grains.
102.0 - 103.2m	Unit 3 - sparsely sandy, stromatoporoid-coral bioclastic floatstone. Common tabular and domal stromatoporoid fragments, also thamnoporid coral fragments.
103.2 - 103.8m	Unit 4 - sandy, peloidal, intraclast packstone-grainstone.
103.8 - 107.0m	Unit 5 - massive, planar to cross-laminated calcareous sandstone. Well-rounded and sorted fine quartz grains.
107.0 - 107.8m	Unit 6 - calcareous sandstone with tabular and domal stromatoporoids. Well rounded quartz grains.
107.8 - 108.6m	Unit 7 - sandy lime mudstone-wackestone. Well-rounded quartz grains.
108.6 - 109.6m	Unit 8 - tan to whitish, massive peloidal packstone-grainstone; rare *Amphipora* and small thamnoporid fragments; sparsely sandy.
109.6 - 111.0m	Unit 9 - brown, thin- to medium-bedded, micritic lime mudstone; thin sandy and sandstone pulses at base of unit.
111.0 - 111.7m	Unit 10 - tan-grey-bluish, mottled lime mudstone; sparsely sandy.
111.7 - 113.4m	Unit 11 - Sparsely fossiliferous mudstone-wackestone-packstone. Out of place(?).
	—base of core—
	NOTE: core was out of place in lower 3 boxes (dropped?) therefore facies associations not reliable!

CANADA CEMENT LAFARGE 85-17
Oxford Co., West Zorra Tp.; Lot 2, Conc. III
(Core #952)

Drill Hole 28
(this study)

Lucas Fm.

0.0 - 2.0m	Unit 1 - dark brown, micritic lime mudstone-wackestone; recrystallized coral fragments common.
2.0 - 4.5m	Unit 2 - light brown-brown, moderately fossiliferous stromatoporoid-coral wackestone-floatstone-bindstone-framestone. Thin, irregular and tabular stromatoporoids grade up to domal and massive types at top. *Amphipora* uncommon. Very fine- to fine-crystalline mudstone-wackestone matrix, wispy microstylolites common.
4.5 - 10.1m	Unit 3 - tan to brown, massive, sparsely fossiliferous, dense micritic lime mudstone interbedded with very fine-crystalline, sparsely fossiliferous lime wackestones-mudstones. Thin bed with ~6 cm tabular stromatoporoid overlain by *Amphipora* floatstone-rudstone, capped by thin peloidal grainstone pulse, and immediately overlain by massive micritic mudstone. Common *Leiosphaerid* algae with very fine- to fine-grained peloids. Sparse, subrounded, very fine- to fine-grained quartz sand.
10.1 - 11.0m	Unit 4 - dark to light brown *Amphipora* rudstone with rare thin irregular stromatoporoids and coral fragments grading up to *Amphipora* floatstone; very fine-grained peloidal packstone pulses.
11.0 - 13.4m	Unit 5 - brown, massive micritic lime mudstone with uncommon recrystallized *Amphipora* and rugose coral fragments. Argillaceous, carbonaceous seams more common upward.
13.4 - 15.7m	Unit 6 - light grey to cream, massive micritic lime mudstone with rare *Amphipora* and small fenestrae. Solitary domal stromatoporoid (recrystallized) above thin *Amphipora*-coral pulse at ~15.5 m.
15.7 - 18.0m	Unit 7 - tan-light brown, moderately fossiliferous *Amphipora*-thamnoporid-colonial rugose coral fragment floatstone pulses in a wackestone matrix. Fossiliferous pulses slightly carbonaceous with common microstylolitic seams.
18.0 - 19.0m	Unit 8 - massive, grey, sparsely fossiliferous mudstone-wackestone; wispy stylolitic seams.
19.9 - 19.9m	Unit 9 - massive *Amphipora* floatstone grading upward to a fenestral, peloidal packstone.
19.9 - 23.4m	Unit 10 - light grey to tan to brown, massive micritic limestone; mudstone-wackestone beds most common with thin, carbonaceous *Amphipora*-colonial rugose coral fragment floatstone pulses uncommonly found.
23.4 - 26.0m	Unit 11 - tan to grey, moderately fossiliferous wackestone-packstone-floatstone. Thin laminar stromatoporoids, small *Amphipora* fragments and uncommon rugose coral fragments. Massive, sparsely fossiliferous wackestone beds. Slightly pyritized zone (~5 cm thick) at ~25.8 m.
26.0 - 28.1m	Unit 12 - brown-dark brown-black, *Amphipora*-irregular stromatoporoid rudstone-floatstone to boundstones. Rudstones constitute ~40% of unit. *Amphipora* delicate at base, robust at top of unit. Uncommon colonial rugose branches.
28.1 - 29.0m	Unit 13 - dark brown-brown, bituminous tabular stromatoporoid-thamnoporid boundstone to floatstone in a wackestone-floatstone matrix.

Amherstburg Fm.

29.0 - 30.0m	Unit 14 - bituminous tabular stromatoporoid-rugose coral boundstone to floatstone.

Appendix F

Existing Geochemical Data for Canada Cement Lafarge Core 85-17 (Drill Hole 28)

Appendix F. Existing geochemical data for Canada Cement Lafarge core 85-17 (drill hole 28, this study).

Sample	**CCL-1**	**CCL-2**	**CCL-3**	**CCL-4**	**CCL-5**	**CCL-6**	**CCL-7**	**CCL-8**	**CCL-9**	**CCL-10**
Depth (m)	0.3	3.0	6.1	9.1	12.2	15.2	18.3	21.3	24.4	27.4
Facies	A3	A4P	A3	A3	A3	A3	A3	A3	A3	A4D
SiO_2 (%)	0.22	0.48	0.77	0.35	0.53	0.46	0.63	0.57	0.42	0.39
TiO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe_2O_3	0.04	0.53	0.04	0.02	<0.01	0.03	0.02	<0.01	0.06	0.10
MnO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.48	0.58	0.92	0.78	0.81	1.14	1.29	1.17	0.87	1.73
CaO	55.6	55.3	54.4	55.2	55.2	54.4	54.3	55.3	55.1	53.9
K_2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
P_2O_5	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Na_2O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LOI	43.3	42.5	42.8	43.3	43.0	43.3	43.3	43.5	43.2	43.6
Total	99.70	99.40	99.00	99.70	99.60	99.40	99.70	100.70	99.70	99.90

Appendix G

Sample Locations

Appendix G. Sample locations.

Sample	Drill Hole Name	Drill Hole (this study)	Depth (m)	Facies
OGS-1	OGS-82-2	8	152.45	A3
OGS-2			155.43	A4D
OGS-3			158.88	A3
OGS-4			162.43	A3
OGS-5			164.08	A4
OGS-6			166.00	A3
OGS-7			167.50	A3
OGS-8			170.37	A3
OGS-9			173.90	A3
OGS-10			176.56	A3
CNS-1	Cansalt DDH 87-3	1	32.92	M4
CNS-2			36.06	M3/M4
CNS-3			42.62	M3
CNS-4			46.19	M3
CNS-5			49.43	M3
CON3-1	Consumers 33409	6	120.51	COLUMBUS
CON3-2			124.23	A3
CON3-3			129.50	A3
CON3-4			133.51	A4P
CON3-5			140.12	A1
CONA-1	Consumers Amoco 13076	18	100.99	A5
CONA-2			104.55	A3
CONA-3			107.76	A3
CONA-4			112.38	A3
CONA-5			115.44	A3
CONA-6			118.55	A3
CONA-7			121.29	AMHERSTBURG
IMPC-1	Imperial 661 Cor. 18	14	194.10	M3/M4
IMPC-2			197.14	M3/M4
IMPC-3			202.82	M3/M4
IMPC-4			210.56	M3/M4
IMPC-5			215.12	M3
IMPC-6			219.90	M3
IMPR-1	Imperial et al. 813	4	41.55	M3
IMPR-2			44.34	M4
IMPR-3			48.81	M4
IMPR-4			51.57	M3
IMPR-5			54.32	M4
IMPR-6			57.63	M3
IMPR-7			60.42	M4
IMPR-8			62.56	AMHERSTBURG

Appendix G. continued

Sample	Drill Hole Name	Drill Hole (this study)	Depth (m)	Facies
CWT-1	Consolidated W. CT-1 (#5)		64.91	A3
CWT-2			67.46	A3
CWT-3			71.04	A5
CWT-4			72.48	A1
CWT-5			75.02	A1
CWT-6			77.32	A4
CWT-7			80.16	A3
IMPE-1	Imperial 813 (#10)		102.45	M3
IMPE-2			111.05	M3
IMPE-3			116.94	M3/M4
IMPE-4			120.64	M3/M4
IMPE-5			125.91	M4
IMPE-6			127.93	M4
CMS-1	OGS-82-3 (#26)		133.44	A1/A3
CMS-2			138.95	A1/A3
CMS-3			142.25	A3
CMS-4			145.44	A1
CMS-5			150.89	A3
CMS-7			154.05	AMHERSTBURG
LAMB-1	OGS-82-1 (#51)		273.08	M3
LAMB-2			277.64	M3
LAMB-4			286.51	M4
LAMB-6			297.06	M3/M4
LAMB-8			306.85	M4
LAMB-9			313.16	M3/M4
LAMB-10			317.25	M4
LAMB-11			322.02	M3/M4
LAMB-12			329.70	M4
LAMB-13			335.52	M4
LAMB-16			342.02	AMHERSTBURG

Appendix H

Analytical Techniques

Appendix H. Analytical techniques.

The following is a brief description about the techniques used and estimated analytical errors for the analyses performed on Lucas Formation samples at the Geochemistry Labs, University of Western Ontario, London, Ontario, in August 1992 and February 1993.

All samples were analyzed for 10 major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, K, Na and P), reported as percent oxides, and 5 trace elements (Pb, Zn, Cu, Ni and Cr). Both major and trace element analyses were performed on a Philips PW-1450 automatic sequential wavelength-dispersive, X-ray fluorescence spectrometer.

Major oxide analysis was done following the "heavy absorber fusion technique" of Norrish and Hutton (1969). Fluorescence X-ray K_a lines of the 10 elements were measured. Nominal compositions were calculated against the standard (G-16) and inter-element influence (matrix) corrections were done by iteration. Loss on ignition (LOI) was determined separately by calculating weight loss after heating a 1 g sample in a muffler furnace for 2 hours at about 1000°C.

Trace element analyses were done on pressed powder pellets. A LiF-200 crystal was used to detect fluorescence X-rays. Mass absorption coefficients were determined using the $RhK_{a(c)}$ Compton peak intensity following the method of Nisbet, Dietrich and Esenwein (1979). Stripping factor for spectral interferences, such as Ti on V and V on Cr, were predetermined on synthetic interference standards. Twenty-eight international rock standard reference materials were used for calibrations.

The precision is better than 5% for both major and trace element determinations, except for P_2O_5 <0.2 weight % and MnO < 0.1 weight%, which have precisions of 15%, and Cr, a precision of 10%.

Appendix I

Whole Rock Chemical Analysis of Lucas Formation Samples

Appendix I. Whole rock chemical analysis of Lucas Formation samples. Analytical results reported in percent (%).

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	P_2O_5	Na_2O	LOI	Total
OGS-1	0.65	0.00	0.00	0.09	0.01	3.65	52.39	0.00	0.00	0.00	43.67	100.46
OGS-2	0.18	0.00	0.00	0.19	0.00	1.72	54.48	0.00	0.00	0.00	43.33	99.90
OGS-3	0.45	0.00	0.00	0.17	0.01	9.09	44.94	0.00	0.00	0.00	45.10	99.76
OGS-4	3.67	0.00	0.03	0.41	0.00	19.41	40.21	0.00	0.00	0.00	35.34	99.07
OGS-5	0.32	0.00	0.00	0.11	0.01	3.58	51.42	0.00	0.00	0.00	43.79	99.23
OGS-6	0.52	0.00	0.00	0.16	0.00	1.26	55.26	0.00	0.00	0.00	42.70	99.90
OGS-7	1.40	0.00	0.00	0.15	0.00	7.39	42.46	0.00	0.00	0.00	46.92	98.32
OGS-8	1.92	0.00	0.00	0.18	0.00	8.01	42.51	0.00	0.00	0.00	46.19	98.81
OGS-9	2.94	0.00	0.19	0.31	0.00	14.09	37.20	0.03	0.00	0.00	43.97	98.73
OGS-10	0.70	0.00	0.00	0.09	0.00	3.23	52.85	0.00	0.00	0.00	43.71	100.58
CNS-1	0.39	0.00	0.00	0.07	0.00	17.78	33.13	0.00	0.00	0.00	46.09	97.46
CNS-2	0.30	0.00	0.00	0.07	0.00	19.48	31.52	0.00	0.00	0.00	46.59	97.96
CNS-3	1.38	0.00	0.00	0.07	0.00	19.67	31.33	0.00	0.00	0.00	45.89	98.34
CNS-4	1.19	0.00	0.00	0.10	0.00	10.20	44.58	0.00	0.00	0.00	43.94	100.01
CNS-5	2.02	0.00	0.00	0.15	0.01	19.54	32.51	0.00	0.00	0.00	43.26	97.49
CON3-1	4.89	0.00	0.00	0.89	0.02	18.45	30.72	0.00	0.00	0.00	43.20	98.17
CON3-2	0.13	0.00	0.00	0.06	0.01	4.55	48.92	0.00	0.00	0.00	43.94	97.61
CON3-3	2.08	0.00	0.00	0.06	0.01	2.59	51.35	0.00	0.00	0.00	42.07	98.16
CON3-4	0.65	0.00	0.00	0.09	0.00	8.32	44.87	0.00	0.00	0.00	45.06	98.99
CON3-5	1.94	0.00	0.00	0.21	0.01	18.73	31.56	0.00	0.00	0.00	45.65	98.10
CONA-1	0.12	0.00	0.00	0.15	0.00	1.54	53.76	0.00	0.00	0.00	43.37	98.94
CONA-2	0.27	0.00	0.00	0.02	0.00	1.78	52.41	0.00	0.00	0.00	43.64	98.12
CONA-3	0.32	0.00	0.00	0.04	0.00	0.80	55.81	0.00	0.00	0.00	43.06	100.03
CONA-4	0.31	0.00	0.00	0.05	0.00	1.82	54.15	0.00	0.00	0.00	43.70	100.03
CONA-5	0.39	0.00	0.00	0.05	0.00	0.84	54.00	0.00	0.00	0.00	43.28	98.56
CONA-6	0.43	0.00	0.00	0.08	0.01	1.22	53.86	0.00	0.00	0.00	43.34	98.94
CONA-7	0.21	0.00	0.00	0.08	0.00	2.41	52.18	0.00	0.00	0.00	43.23	98.11
IMPC-1	0.55	0.00	0.00	0.13	0.01	4.13	51.05	0.00	0.00	0.00	44.27	100.14
IMPC-2	0.33	0.00	0.00	0.33	0.01	11.80	41.34	0.00	0.00	0.00	45.14	98.95
IMPC-3	0.32	0.00	0.00	0.17	0.00	19.26	31.97	0.00	0.00	0.00	47.24	98.96
IMPC-4	0.98	0.00	0.00	0.17	0.01	20.31	30.94	0.00	0.00	0.00	47.04	99.45
IMPC-5	0.40	0.00	0.00	0.23	0.02	20.88	32.82	0.00	0.00	0.00	44.53	98.88
IMPC-6	0.43	0.00	0.00	0.13	0.01	20.87	33.09	0.00	0.00	0.00	44.04	98.57
IMPR-1	0.84	0.00	0.00	0.33	0.02	19.08	33.41	0.00	0.00	0.00	46.20	99.88
IMPR-2	0.71	0.00	0.00	0.09	0.01	0.78	55.37	0.00	0.00	0.00	42.59	99.55
IMPR-3	0.55	0.00	0.00	0.15	0.03	20.56	31.29	0.00	0.00	0.00	46.37	98.95
IMPR-4	1.21	0.00	0.00	0.16	0.02	20.81	31.03	0.00	0.00	0.00	46.62	99.85

Appendix I. continued

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	P_2O_5	Na_2O	LOI	Total
IMPR-5	0.11	0.00	0.00	0.17	0.00	20.29	31.64	0.00	0.00	0.00	46.51	98.72
IMPR-6	1.64	0.00	0.00	0.18	0.01	20.36	30.69	0.00	0.00	0.00	45.95	98.83
IMPR-7	2.83	0.00	0.15	0.34	0.01	20.05	30.21	0.00	0.00	0.00	45.17	98.76
IMPR-8	2.68	0.00	0.01	0.28	0.01	20.10	30.41	0.00	0.00	0.00	45.25	98.74
CWT-1	0.26	0.00	0.00	0.09	0.00	0.68	54.71	0.00	0.00	0.00	42.99	98.73
CWT-2	0.75	0.00	0.00	0.14	0.00	5.79	49.13	0.00	0.00	0.00	43.81	99.62
CWT-3	1.32	0.00	0.00	0.04	0.00	0.41	55.04	0.00	0.00	0.00	42.56	99.37
CWT-4	1.37	0.01	0.00	0.15	0.00	6.26	48.16	0.00	0.00	0.00	43.24	99.19
CWT-5	0.67	0.00	0.00	0.05	0.00	1.33	55.20	0.00	0.00	0.00	42.56	99.81
CWT-6	0.61	0.00	0.00	0.08	0.00	5.77	49.18	0.00	0.00	0.00	43.81	99.45
CWT-7	0.84	0.00	0.00	0.12	0.00	15.92	36.73	0.00	0.00	0.00	45.98	99.59
CWT-7(d)	0.88	0.00	0.00	0.12	0.00	16.12	36.57	0.00	0.00	0.00	45.61	99.30
IMPE-1	0.54	0.00	0.00	0.14	0.01	1.47	52.22	0.00	0.00	0.00	44.01	98.39
IMPE-2	0.67	0.00	0.00	0.23	0.01	14.15	37.10	0.00	0.00	0.00	47.37	99.53
IMPE-3	8.86	0.00	0.00	0.19	0.01	17.37	30.36	0.00	0.00	0.00	43.27	100.06
IMPE-4	0.71	0.00	0.00	0.17	0.01	19.65	33.21	0.00	0.00	0.00	45.98	99.73
IMPE-5	1.04	0.01	0.00	0.17	0.01	20.72	31.01	0.00	0.00	0.00	46.61	99.57
IMPE-6	0.04	0.00	0.00	0.03	0.00	3.85	51.90	0.00	0.00	0.00	43.91	99.73
CMS-1	2.89	0.01	0.23	0.23	0.00	1.20	53.23	0.00	0.00	0.00	41.77	99.56
CMS-2	0.40	0.00	0.00	0.04	0.00	1.76	54.20	0.00	0.00	0.00	43.28	99.68
CMS-3	0.04	0.00	0.00	0.04	0.00	0.61	55.28	0.00	0.00	0.00	43.21	99.18
CMS-4	0.14	0.00	0.00	0.01	0.00	0.50	56.25	0.00	0.00	0.00	42.87	99.77
CMS-5	0.28	0.00	0.00	0.04	0.00	1.08	55.07	0.00	0.00	0.00	43.41	99.88
CMS-7	0.74	0.00	0.00	0.15	0.00	2.69	52.42	0.00	0.00	0.00	43.07	99.07
LAMB-1	1.94	0.00	0.00	0.52	0.01	20.87	30.08	0.00	0.00	0.00	45.35	98.77
LAMB-2	0.14	0.00	0.00	0.05	0.00	21.50	31.14	0.00	0.00	0.00	46.77	99.60
LAMB-4	0.21	0.00	0.00	0.04	0.00	18.90	32.53	0.00	0.00	0.00	44.42	96.10
LAMB-6	0.14	0.00	0.00	0.04	0.00	20.77	30.63	0.00	0.00	0.00	46.77	98.35
LAMB-8	0.09	0.00	0.00	0.02	0.00	16.21	33.74	0.00	0.00	0.00	43.15	93.21
LAMB-9	0.08	0.00	0.00	0.02	0.00	21.18	30.64	0.00	0.00	0.00	47.57	99.49
LAMB-10	0.10	0.00	0.00	0.03	0.00	7.67	47.30	0.00	0.00	0.00	43.45	98.55
LAMB-11	0.20	0.00	0.00	0.04	0.00	20.81	31.57	0.00	0.00	0.00	46.91	99.53
LAMB-12	0.12	0.00	0.00	0.02	0.00	10.33	44.34	0.00	0.00	0.00	44.83	99.64
LAMB-13	0.29	0.00	0.00	0.03	0.00	17.85	34.91	0.00	0.00	0.00	46.73	99.81
LAMB-16	0.02	0.00	0.00	0.02	0.00	1.04	55.57	0.00	0.00	0.00	42.67	99.32

Appendix J

Trace Element Analysis of Lucas Formation Samples

Appendix J. Trace element analysis of Lucas Formation samples. Analytical results reported in ppm.

Sample	Pb	Zn	Cu	Ni	Cr	V
CNS-1	<5	6	<5	<5	57	6
CNS-3	<5	<5	<5	<5	28	7
CNS-5	9	6	53	<5	21	8
CON3-1	<5	7	<5	<5	11	8
CON3-3	<5	5	7	<5	<5	<5
CON3-5	7	7	<5	<5	<5	<5
CONA-3	<5	<5	<5	<5	<5	<5
CONA-5	<5	<5	<5	<5	<5	6
CONA-7	<5	1183	<5	<5	<5	7
IMPC-1	5	<5	<5	<5	<5	<5
IMPC-3	<5	5	<5	<5	<5	9
IMPC-5	<5	<5	<5	<5	<5	<5
IMPR-1	6	9	<5	<5	14	6
IMPR-3	<5	6	<5	<5	<5	7
IMPR-5	<5	<5	<5	<5	<5	<5
IMPR-7	<5	10	<5	<5	<5	7
OGS-1	5	<5	<5	<5	<5	<5
OGS-3	<5	<5	<5	<5	<5	<5
OGS-5	8	6	6	<5	<5	<5
OGS-7	<5	<5	936	<5	<5	69
OGS-9	9	7	<5	<5	<5	9
CWT-1	<5	31	17	<5	<5	
CWT-2	<5	16	16	5	<5	
CWT-3	96	23	14	<5	<5	
CWT-4	<5	16	11	<5	<5	
CWT-5	<5	12	13	<5	<5	
CWT-6	<5	16	11	<5	<5	
CWT-7	<5	12	6	<5	<5	
IMPE-1	<5	8	7	<5	<5	
IMPE-2	<5	16	8	<5	<5	
IMPE-3	<5	14	7	<5	<5	
IMPE-5	<5	7	<5	<5	<5	
IMPE-6	<5	7	10	<5	<5	
CMS-1	<5	6	12	<5	<5	
CMS-2	<5	7	11	<5	<5	
CMS-3	5	5	13	<5	<5	
CMS-4	<5	5	12	<5	<5	
CMS-5	5	6	15	<5	<5	
CMS-7	<5	<5	14	<5	<5	
LAMB-1	<5	5	18	<5	<5	
LAMB-2	<5	6	16	<5	<5	
LAMB-4	<5	6	9	<5	<5	
LAMB-6	9	<5	9	<5	<5	
LAMB-8	7	<5	8	<5	<5	
LAMB-9	<5	7	13	<5	<5	
LAMB-10	<5	7	10	<5	<5	
LAMB-11	<5	7	12	<5	<5	
LAMB-12	<5	7	12	<5	<5	
LAMB-13	<5	5	10	6	<5	
LAMB-16	<5	2671	9	8	<5	

Appendix K

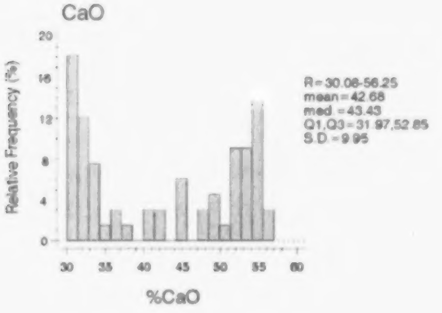
Histograms

Key

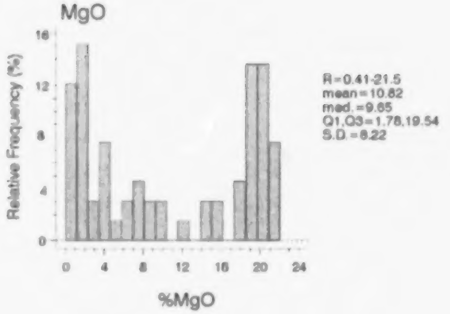
R = range in values
Q_1 = 25th percentile
Q_3 = 75th percentile
med = median
SD = standard deviation

*N.B.:
- Histograms for facies M3 and M4 include data from intervals assigned to facies M3/M4.
- Vertical scales vary from histogram to histogram.

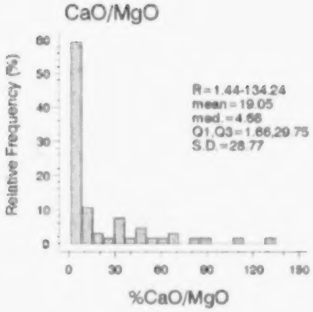
Entire Lucas Formation Geochemical Data (n = 66)



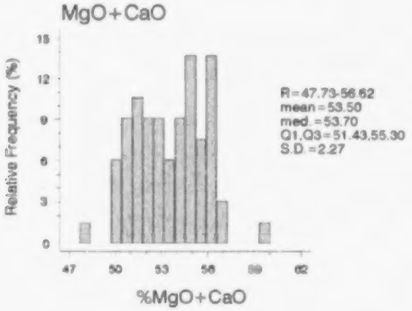
R = 30.08-56.25
mean = 42.68
med. = 43.43
Q1,Q3 = 31.97,52.85
S.D. = 9.95



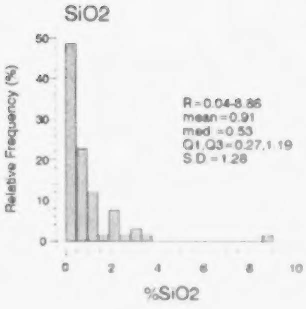
R = 0.41-21.5
mean = 10.82
med. = 9.65
Q1,Q3 = 1.78,19.54
S.D. = 8.22



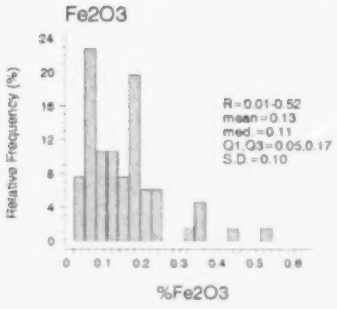
R = 1.44-134.24
mean = 19.05
med. = 4.66
Q1,Q3 = 1.66,29.75
S.D. = 28.77



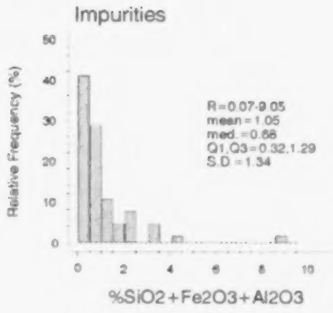
R = 47.73-56.62
mean = 53.50
med. = 53.70
Q1,Q3 = 51.43,55.30
S.D. = 2.27



R = 0.04-8.86
mean = 0.91
med. = 0.53
Q1,Q3 = 0.27,1.19
S.D. = 1.28



R = 0.01-0.52
mean = 0.13
med. = 0.11
Q1,Q3 = 0.05,0.17
S.D. = 0.10

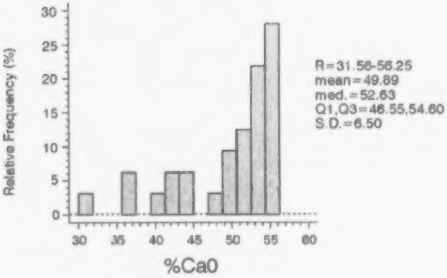


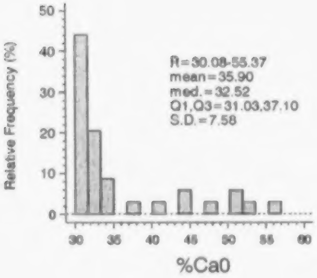
R = 0.07-9.05
mean = 1.05
med. = 0.68
Q1,Q3 = 0.32,1.29
S.D. = 1.34

APPALACHIAN BASIN (n=32)

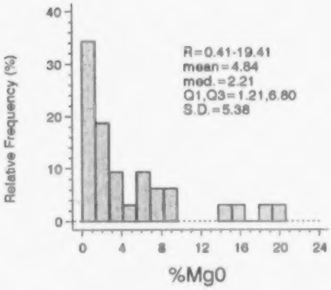
MICHIGAN BASIN (n=34)

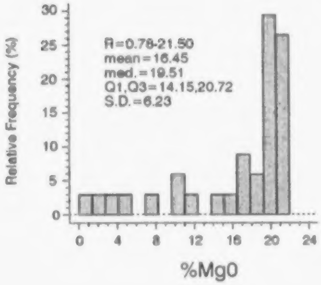
Ca0



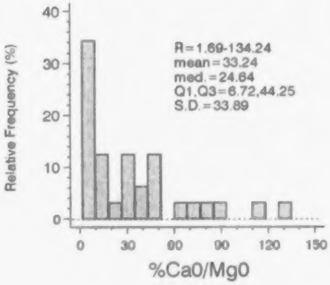


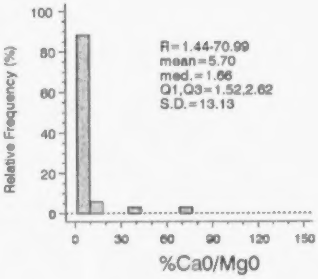
Mg0



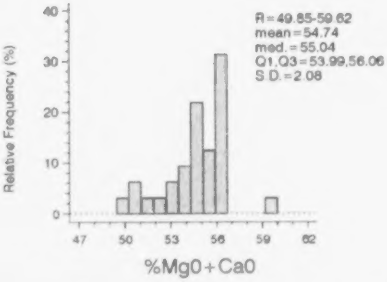


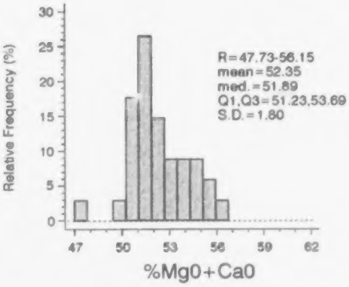
Ca0/Mg0





Mg0+Ca0

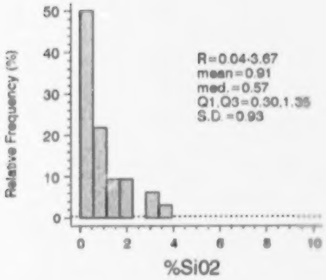


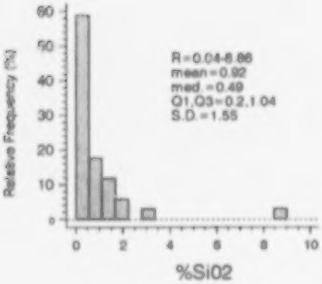


APPALACHIAN BASIN (n=32)

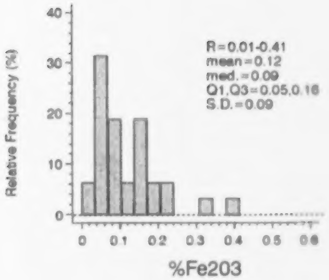
MICHIGAN BASIN (n=34)

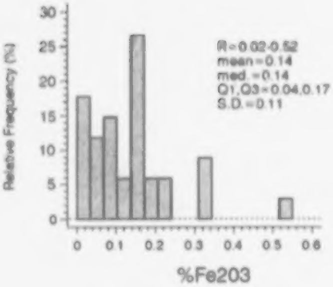
Si02



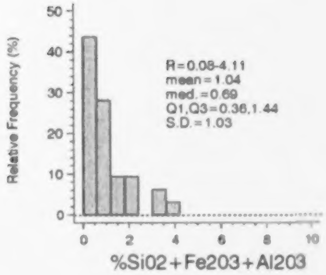


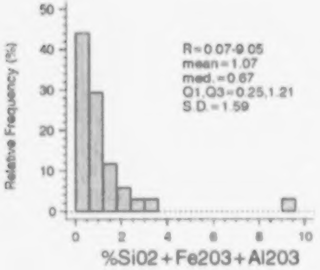
Fe203



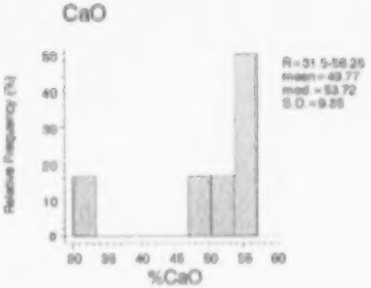


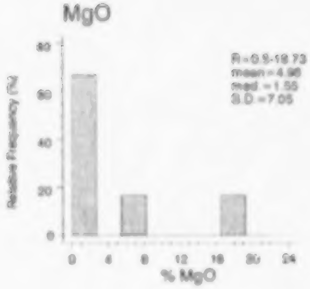
Total
Impurities

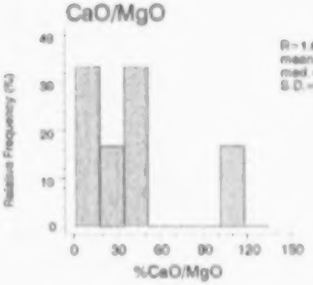


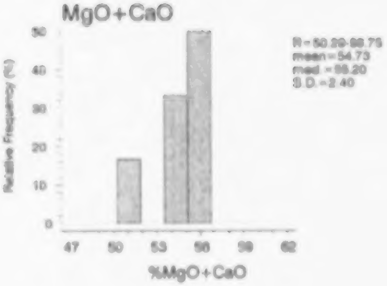


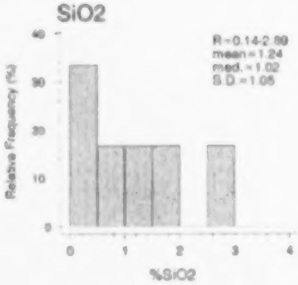
A1 Facies (n=6)

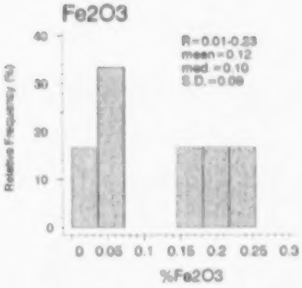

CaO

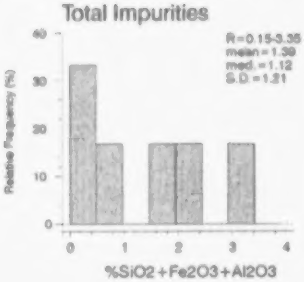

MgO


CaO/MgO

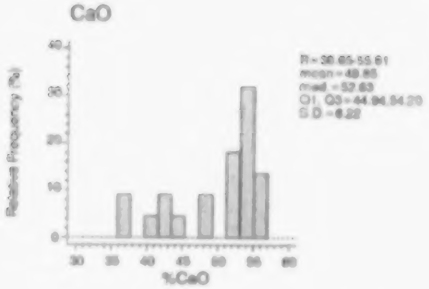

MgO+CaO

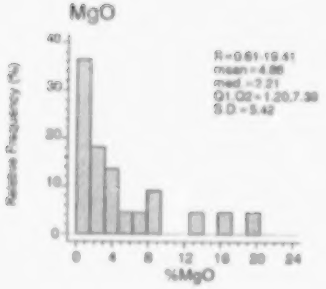

SiO2

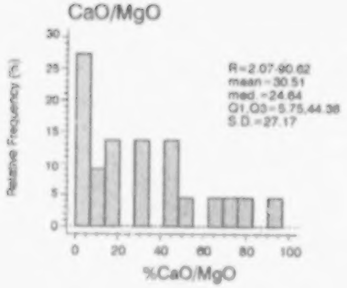

Fe2O3

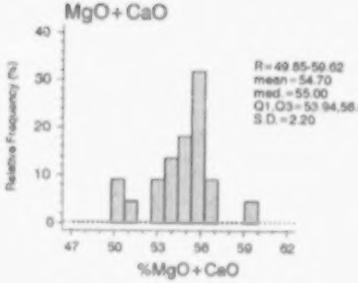

Total Impurities

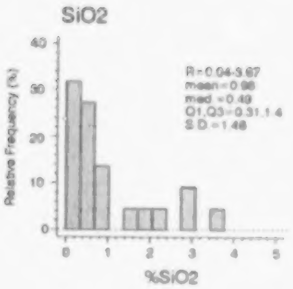
A3 Facies (n = 22)

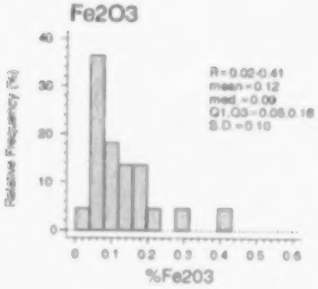

CaO

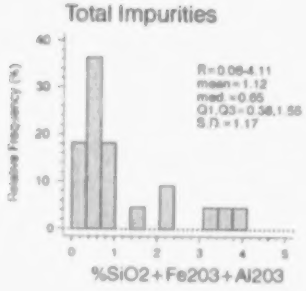

MgO


CaO/MgO

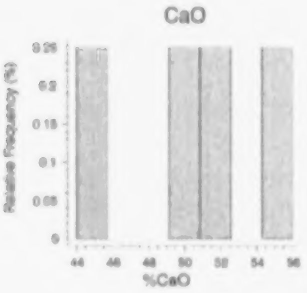

MgO + CaO

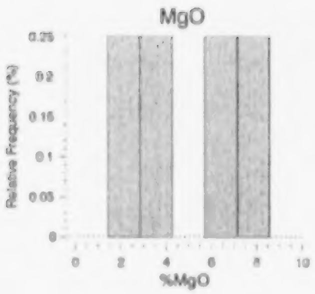

SiO2

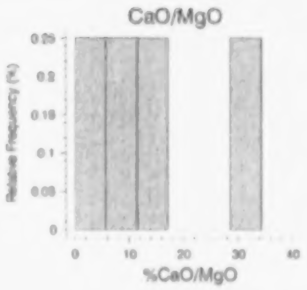

Fe2O3

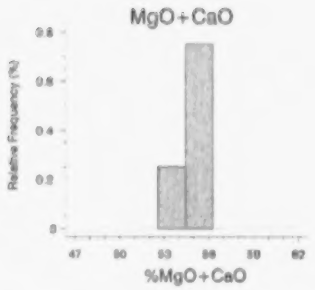

Total Impurities

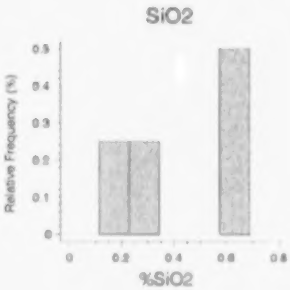
A4 Facies (n = 4)

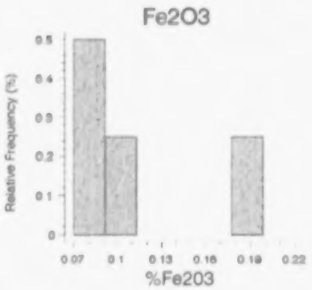

CaO

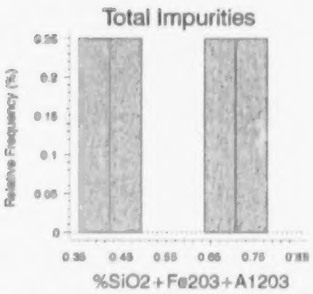

MgO


CaO/MgO

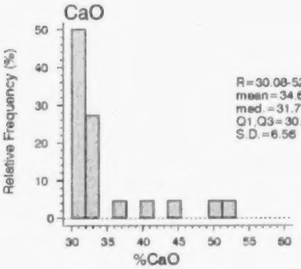

MgO+CaO

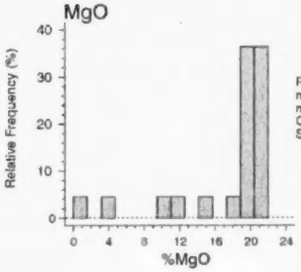

SiO2

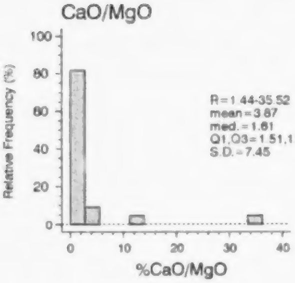

Fe2O3

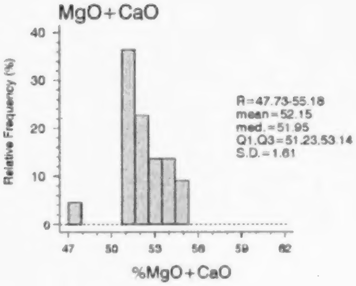

Total Impurities

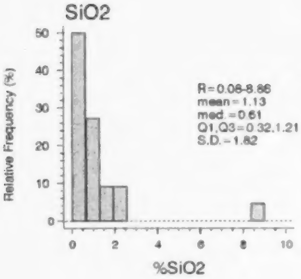
M3 Facies* (n = 22)

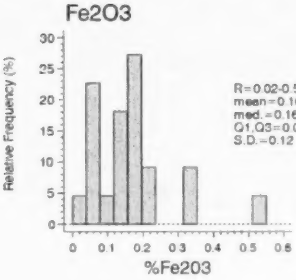


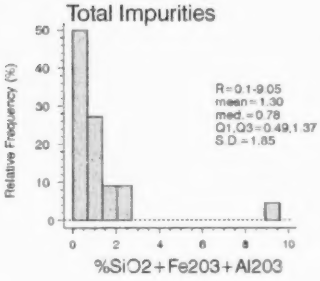






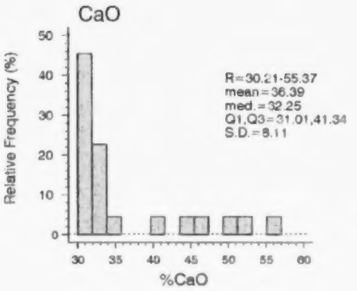


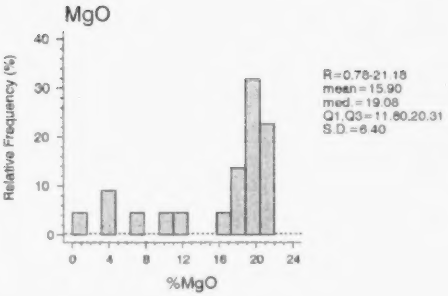


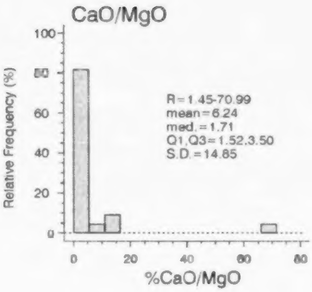


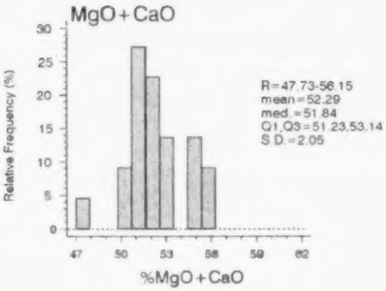
* Includes data from units labelled Facies M3/M4

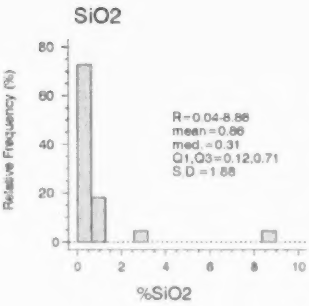
M4 Facies * (n=22)

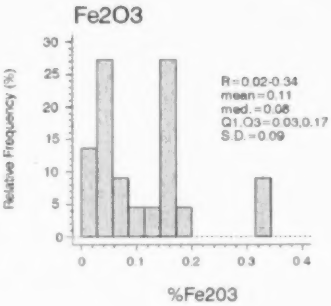


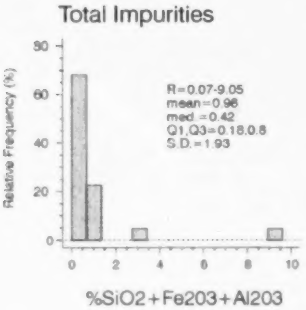












Metric Conversion Table

Conversion from SI to Imperial			**Conversion from Imperial to SI**		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
LENGTH					
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
AREA					
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
MASS					
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

ISSN 0826-9580
ISBN 0-7794-5909-1